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The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsquent meeting.

1.	William Clift	1870.1872	New York, N. Y.
2.	William Clift	1872–1873	Albany, N. Y.
3.	William Clift	1873–1874	New York, N. Y.
4.	Robert B. Roosevelt	1874–1875	New York, N. Y.
5.	Robert B. Roosevelt	1875–1876	New York, N. Y.
6.	Robert B. Roosevelt	1876–1877[1]	New York, N. Y.
7.	Robert B. Roosevelt	1877–1878	New York, N. Y.
8.	Robert B. Roosevelt	1878–1879	New York, N. Y.
9.	Robert B. Roosevelt	1879–1880	New York, N. Y.
10.	Robert B. Roosevelt	1880–1881	New York, N. Y.
11.	Robert B. Roosevelt	1881–1882	New York, N. Y.
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14.	Theodore Lyman	1884–1885	Washington, D. C.
15.	Marshall McDonald	1885–1886	Washington, D. C.
16.	W. M. Hudson	1886–1887	Chicago, Ill.
17.	William L. May	1887–1888	Washington, D. C.
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19.	Eugene G. Blackford	1889–1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890–1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891–1892	Washington, D. C.
22.	Herschel Whitaker	1892–1893	New York, N. Y.
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35.	C. D. Joslyn	1905–1906	White Sulphur Springs, W. Va.
36.	E. A. Birge	1906–1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907–1908	Erie, Pa.
38.	Tarleton H. Bean	1908–1909	Washington, D. C.
39.	Seymour Bower	1909–1910	Toledo, Ohio
40.	William E. Meehan	1910–1911	New York, N. Y.
41.	S. F. Fullerton	1911–1912	St. Louis, Mo.

[1] A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

42.	Charles H. Townsend	1912–1913	Denver, Colo.
43.	Henry B. Ward	1913–1914	Boston, Mass.
44.	Daniel B. Fearing	1914–1915	Washington, D. C.
45.	Jacob Reighard	1915–1916	San Francisco, Calif.
46.	George W. Field	1916–1917	New Orleans, La.
47.	Henry O'Malley	1917–1918	St. Paul, Minn.
48.	M. L. Alexander	1918–1919	New York, N. Y.
49.	Carlos Avery	1919–1920	Louisville, Ky.
50.	Nathan R. Buller	1920–1921	Ottawa, Ont.
51.	William E. Barber	1921–1922	Allentown, Pa.
52.	Glen C. Leach	1922–1923	Madison, Wis.
53.	George C. Embody	1923–1924	St. Louis, Mo.
54.	Eben W. Cobb	1924–1925	Quebec, P. Q.
55.	Charles O. Hayford	1925–1926	Denver, Colo.
56.	John W. Titcomb	1926–1927	Mobile, Ala.
57.	Emmeline Moore	1927–1928	Hartford, Conn.
58.	C. F. Culler	1928–1929	Seattle, Wash.
59.	David L. Belding	1929–1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930–1931	Toronto, Ont.
61.	James A. Rodd	1931–1932	Hot Springs, Ark.
62.	H. S. Davis	1932–1933	Baltimore, Md.
63.	Fred A. Westerman	1933–1934	Columbus, Ohio
64.	E. L. Wickliff	1934–1935	Montreal, P. Q.
65.	Frank T. Bell	1935–1936	Tulsa, Okla.
66.	A. G. Huntsman	1936–1937	Grand Rapids, Mich.
67.	I. T. Quinn	1937–1938	Mexico City, Mexico
68.	Fred J. Foster	1938–1939	Asheville, N. C.
69.	T. H. Langlois	1939–1940	San Francisco, Calif.
70.	James Brown	1940–1941	Toronto, Ont.
71.	John Van Oosten	1941–1942	St. Louis, Mo.
72.	John Van Oosten	1942–1943	(No meeting)[2]
73.	John Van Oosten	1943–1944	(No meeting)[3]
74.	John Van Oosten	1944–1945	(No meeting)[3]
75.	John Van Oosten	1945–1946	(No meeting)[3]
76.	Joseph R. Hogan	1946–1947	St. Paul, Minn.
77.	H. H. MacKay	1947–1948	Denver, Colo.
78.	Seth Gordon	1948–1949	Atlantic City, N. J.
79.	Milton C. James	1949–1950	Winnipeg, Man.
80.	Albert S. Hazzard	1950–1951	Memphis, Tenn.
81.	W. J. K. Harkness	1951–1952	Rochester, N. Y.
82.	Ralph Hile	1952–1953	Dallas, Texas
83.	Fred A. Thompson	1953–1954	Milwaukee, Wis.
84.	A. L. Pritchard	1954–1955	Seattle, Wash.
85.	G. E. Sprecher	1955–1956	Augusta, Ga.

2 The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

3 No annual meeting scheduled because of the war.

In Memoriam

David D. Palmer, Entiat, Washington

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Part 1
Papers

TUNA RESOURCES OF THE TROPICAL AND SUB-TROPICAL WESTERN ATLANTIC

Stewart Springer

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Washington, D. C.

Abstract

Eight species of tunas and bonitos are known to occur in the Gulf of Mexico, Caribbean Sea, and adjacent Atlantic waters. Seven of these have been utilized, at least on a small scale, in commercial packs of canned tuna. Gulf and Caribbean catches of some species have been processed for the first time as recently as 1955.

The presence of tuna as a widely distributed resource available to longlines was demonstrated by the U. S. Fish and Wildlife Service exploratory fishing vessel *Oregon* in 1954 and 1955, supporting the views of a few earlier observers that the rare appearance of large numbers of tuna in Gulf and Caribbean offshore waters indicated the existence of a diverse but substantial sub-surface population.

Effective exploitation of the resource and the development of a prosperous longline fishery probably depends on many factors, not limited to, but including the development of a stable market at locations convenient to fishermen and rapid extension of our knowledge of the areas and seasons for best fishing.

Species of Tunas in the Gulf and Caribbean

In May 1954, the exploratory fishing vessel *Oregon* of the U. S. Fish and Wildlife Service began a series of cruises during which experimental fishing was carried on with longline gear (Captiva, 1955) adapted from gear used by the Japanese in the Pacific. One surprising result was to find that large yellowfin tuna, *Thunnus albacares* (Bonnaterre), were widely distributed in the Gulf of Mexico beyond the 500-fathom curve (Bullis 1955).

Bullis and Mather (1955) reporting on tunas taken on longlines chiefly in the Windward Passage and its southern approaches during a cruise of the *Oregon* in April 1955, presented evidence for the recognition, as valid species, of both the bigeye, *Thunnus obesus* (Lowe), and the Atlantic blackfin, *Thunnus atlanticus* (Lesson). They also give data on the capture on this cruise of: yellowfin tuna; albacore, *Thunnus alalunga* (Gmelin); oceanic bonito or white skipjack, *Katsuwonus pelamis* (Linnaeus); and very large bluefin tuna, *Thunnus thynnus* (Linnaeus). Commercial longline fishing vessels reported landings of five of these six species at Ponce, Puerto Rico, early in 1955. Bluefins were not landed or at least were not recognized. Very large bluefin such as the 300- to 600-pound fish caught on the *Oregon's* longline sets south of Cuba and in the Windward Passage would, very likely, have been rejected by the cannery; but the other species were either used as a part of regular packs of canned tuna or were packed experimentally.

Biological and technological questions are beyond the scope of this report even if the information were available to answer them; but, in general, it can be said that western Atlantic yellowfin, albacore, bluefin, white skipjack, and bigeye tunas are morphologically similar to Pacific tunas bearing the same common names and that the qualities of the Atlantic forms for canning appear likewise to be similar to those of their Pacific counterparts. The little tuna, *Euthynnus alletteratus* (Rafinesque), and the bonito, *Sarda sarda* (Bloch) are similar to Pacific forms and like them have lower value at present for markets in the United States.

The blackfin tuna has no eastern Pacific parallel. In the Gulf and in parts of the Caribbean at least, blackfins are one of the most interesting species from the practical viewpoint because of their apparent abundance and because their flesh is white and presumably is especially desirable to markets that place the albacore in a category of highest quality.

The eight species mentioned are the only tunas known positively from the Gulf and Caribbean region and very little is known about their distribution or life histories. Even the nomenclature is confused but information on the tunas of the area is being accumulated systematically. Biologists assigned to cruises of the *Oregon* have collected large series of postlarval and juvenile tunas in the Gulf of Mexico. Single specimens of the larger tunas and series of smaller ones have been preserved, and selected material has been deposited in the collections of the United States National Museum—an important step in the establishment of a stable nomenclature. Permanent study collections are essential in the initial phase of any comprehensive study of fishes and biological work with Atlantic tunas in the past has been handicapped by the lack of reference material. The series now available in the National Museum should prove useful in future biological studies if augmented by additional collections. The outlook for the future accumulation of significant field information on the biology of Atlantic tunas is promising. Beginning in 1950, when operation of the research vessels *Alaska* and *Oregon* by the Fish and Wildlife Service was started in the offshore waters of the Gulf of Mexico, considerable interest developed in the potentials of the pelagic fishery in the tropical and sub-tropical Atlantic. Important oceanographic and biological programs are being carried out by the Woods Hole Oceanographic Institution, the Department of Oceanography of the Texas A. and M. College, the Marine Laboratory of the University of Miami and other institutions. These programs supplement investigations of the pelagic fisheries and the pelagic environment by the Fish and Wildlife Service. Also, the prior establishment of well-organized investigations of pelagic fishery resources in the Pacific has given impetus to work in the Atlantic.

Indications of Abundance of Tunas in the Gulf and Caribbean

An interest in commercial fishing for tunas of the western Atlantic has developed gradually during and following World War II when food shortages in the West Indies were a matter of concern. Whiteleather and Brown

(1945), impressed by the numbers of blackfins seen in the southeastern Caribbean pointed out the need for further investigations into the availability of the blackfin bonito off Tobago. At the earlier meetings of the Gulf and Caribbean Fisheries Institute at Miami Beach attention was called by Baughman (1949) to frequent but somewhat vague reports of large numbers of tuna in the Gulf of Mexico and by Mowbray (1950) to the variety of tunas present in waters near Bermuda. A small fishery, centered off the Gulf of Batabano on the south coast of Cuba, started in 1940; the techniques were those used by the Japanese in live-bait fishing for blackfin tuna and white skipjack (Rawlings, 1953). The estimated annual catch of 1,00 to 1,500 tons in recent years has been canned locally for the Cuban market.

On August 29, 1951, surfacing schools of tuna were sighted from the *Oregon* early in the morning in the central Gulf of Mexico (at 26° 12′ North, 89° 34′ West. The *Oregon* contained on a northerly course all of that day without once passing out of sight of surfacing tuna schools in the distance of more than 100 miles. The tuna were estimated to weight from 30 to 70 pounds, and although trolling lines used throughout the day failed to catch tuna, the personnel aboard the vessel were convinced that the Gulf held vast stocks. A few days later the *Oregon* left its home port at Pascagoula and, after passing the 200-fathom curve off the mouth of the Mississippi River, again encountered large numbers of surface schools of tuna. At this time, however, the schools sighted (nearer the continental shelf) were made up of smaller fish with weights estimated from 4 to 10 pounds. The few fish caught by trolling were blackfin tuna and the compact schools were feeding in company with whale sharks in the peculiar manner described by Gudger (1941). The sea was especially calm while the tuna were seen at the surface, but a few days later, following a windy period, surface signs of tuna were not observed from the *Oregon*. Furthermore, during the next 2 years, while the *Oregon* was engaged part-time in unsuccessful attempts to catch commercial quantities of Gulf tuna by use of Pacific-coast-type purse seines and live-bait fishing methods, the numbers and sizes of tuna schools observed were comparatively small. Some blackfin tuna and white skipjack were taken by live-bait fishing and five small bluefin tuna were caught by this method in the northern Gulf of Mexico. Only one yellowfin tuna was caught from the *Oregon* up to 1954, but this specimen was the first known to have been taken in the Gulf of Mexico. In 1954 and in the first part of 1955, comparatively few tuna were seen at the surface from the *Oregon* but longline fishing produced good catches of yellowfin.

Three commercial longline vessels, operated in the Gulf of Mexico in the fall and early winter of 1953, took catches of yellowfins sufficient to offer some encouragement. Catches were made at satisfactory rates until January 1955, when large bluefin tuna weighing in excess of 300 pounds began to appear in longline catches. After the first of February yellowfin tuna were not taken and since no market was found for large frozen bluefin tuna, the longline vessels were withdrawn or moved to Ponce, Puerto Rico.

Single sets of longline gear by the *Oregon* indicated that yellowfins were present again in the northern Gulf of Mexico in May 1955. In August 1955, in the northeast Gulf, 14 days of fishing by the *Oregon* with approximately 1,000 longline hooks a day produced 45,000 pounds of good yellowfin tuna. An additional amount, estimated at 14,000 pounds, was lost to sharks

Means of Exploitation of Caribbean and Gulf Stocks of Tuna

Yellowfin tuna in the Gulf and Caribbean area are readily taken on longlines but their irregular appearances at the surface make the outlook for live-bait fishing and purse seining poor. Possibly some additional exploration will bring new fishing grounds to light where conditions for live-bait fishing or purse seining are better. The average weight of all yellowfin tuna taken by the *Oregon* in the Gulf and Caribbean on longlines is close to 100 pounds. Whether the longline gear is selective for the larger fish or whether smaller ones are rare in the fishing areas covered by the *Oregon* exploration remains to be determined.

Blackfin tuna taken in the Gulf by the *Oregon* have had an average weight of about 6 pounds. An estimate of the comparative abundance of the yellowfin and blackfin (Anderson, Stolting, and Associates, 1953) places the blackfin first. Even though a small number of blackfin have been taken on longlines there appears to be no reason to reject this estimate. Smaller hooks on longlines might change the situation materially. However, except for the live-bait fishing method used in the Cuban fishery for blackfin no successful method has been found to take this species in commercial quantities. Trolling for blackfin frequently produces small catches or may be entirely fruitless even while great numbers are near the fishing vessel. Experimental fishing with different methods is needed.

Experimentation with gear should also prove worthwhile in investigations of albacore and bigeye stocks. Neither has yet been taken in the Gulf or west of the Windward Passage.

The large bluefin of the Gulf and upper Caribbean are undesirable from a marketing point of view and damage longlines suitable for yellowfin. It seems at present that this species will be of no commercial interest in the Gulf or Carribbean unless stocks of smaller fish are discovered there. The large bluefin is, of course, valuable as a game fish.

Longline fishing has the advantage over live-bait or purse-seine fishing of comparatively lower costs, particularly where operations can be carried out near a landing point and market.

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BIOLOGICAL CONDITIONS IN A BRINE-POLLUTED STREAM IN OKLAHOMA

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Norman, Oklahoma

AND

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Abstract

A year-round study was made of a prairie stream polluted with brine wastes from oil wells to learn more about the biological conditions in waters high in chlorides. Concentrations ranged from 20,000 p.p.m. chlorides at the headwaters to 100 p.p.m. at the confluence of the brine-polluted stream and a larger stream. The average number of kinds of organisms found in waters with various concentrations of chloride was: 16,000 to 20,000 p.p.m.—4.0; 11,000 to 16,000 p.p.m.—4.8, 8,000 to 11,000 p.p.m.—6.5, 4,000 to 8,000 p.p.m.—8.5, 1,000 to 4,000 p.p.m.—9.3, 100 to 1,000 p.p.m.—13.0. The 34 kinds of organisms in the stream throughout the year are arranged according to their chloride tolerance. These animals include fish, crustaceans, nematodes, insects, rotifers, and protozoans.

Introduction

With the development of the oil industry in the southwestern United States, a number of prairie streams have become polluted with wastes from drilling, pumping, and refining operations. Brine water which usually contains large quantities of sodium, calcium, magnesium, potassium, and chlorides may be pumped to the surface simultaneously with the oil.

The large volumes of salt water which especially characterize the older wells present a problem of disposal, since there is no practical and economical way of removing the various salts from the water. For instance, a large oil field in Texas produced over 2 billion barrels of brine between 1930 and 1954.[1] Up to 1942, brines were stored in large pits for solar evaporation, evaporated by artificial heat, or dumped into the streams. Since then much of the brine has been safely and profitably handled by injecting it into old or newly drilled wells and returning it to the reservoir below. Frequently this injection has increased the subsurface pressure and consequently the flow of oil in neighboring wells.

Injection wells, however, do not usually handle all the brine produced

1 Morris, W. S., 1954. Salt water disposal in the East Texas oil field. Mimeographed by The East Texas Salt Water Disposal Company, Kilgore, Texas. 3 pp.

and in the older fields where the ratio of oil to brine is low, the value of production does not justify the expense of the disposal method. Thus the dumping of brine into the streams or holding it in pits continues and has frequently resulted in the seepage of brine containing as high as 225,000 p.p.m. chlorides into the subsurface water, rendering it unfit for drinking and for industrial, and agricultural uses. The U. S. Public Health Service (1946) recommends a limit of 250 p.p.m. chloride for drinking water. Heller (1933) states that sheep have been able to exist on 2.5-percent solution of sodium chloride and that cattle not in milk production have maintained themselves on water containing 2-percent sodium chloride. As a safe rule, however, he stated that 1.5 percent total salts should be considered the upper limit at which maintenance can be expected. For lactating animals the limit is lower. Insufficient information in regard to the tolerance levels of aquatic organisms to the combined ingredients of brine water renders useless at this time a recommendation for disposal of brine with minimum harm to the organisms in the stream. It was the object of this survey to gather information about the general chemical and biological conditions along a stream receiving brine wastes.

For this purpose, Salt Creek, a brine-polluted tributary of the Little Washita, was chosen. It was particularly well-suited for such a project in that it represented conditions common to many of the prairie streams in the southwest. Typical prairie streams are clear and shallow and have shifting bottoms of sand and rather high banks. These streams usually can be waded except during flood when they are exceptionally turbid, high, and rampant. Salt Creek originates just southeast of the town of Cement and flows southward approximately 5 miles before entering the Little Washita (Fig. 1).

The Little Washita River arises from three head streams which have their source northwest of the town of Cyril. These three streams converge west of Cyril. Whence the river proceeds eastward for approximately 35 miles until it empties into the main Washita River near Ninnekah, Oklahoma. Its watershed of approximately 150,808 acres is drained by countless numbers of small tributaries which cut deeply into the surrounding terrain. The Little Washita itself lies in a gorge which at places is as deep as 30 feet and flows shallowly over a shifting bottom of sand to which some clay and silt are added near its mouth. Low flows of water characterize the stream throughout the greater part of the year and flash floods during the spring rains are responsible for water levels that are quick to rise and quick to subside. The stream flows through deposits of gypsum, sandstone, and dolomite. The basin is tall-grass prairie and postoak-blackjack.

Methods

The effects of the brine pollutants were studied at three stations (10, 12, and 14) on Salt Creek. Three additional stations (9, 15, and 16) were sampled, one above and two below the confluence of Salt Creek and the Little Washita.

FIGURE 1.—Map showing the sampling stations and the relationship of Salt Creek (Station 10, 12, and 14) to the Little Washita River.

The river basin was explored and stations were set up during August 1951, and the area was visited each week whenever weather and other circumstances permitted, until December when the frequency of collections was reduced to every other weekend until June 1952. The Salt Creek study was part of a survey covering the whole drainage basin of the Little Washita. Therefore, samples occasionally were not taken on Salt Creek when attention was needed elsewhere in the basin.

Dissolved oxygen, pH, chlorides, bicarbonate, and free carbon dioxide were determined in the field and sulphates were determined gravimetrically in the laboratory (Standard Methods). Comprehensive inorganic chemical analyses were made daily at a downstream station on the Little Washita by the U. S. Geological Survey.

Temperature readings were taken at each sampling, conductivity measurements were made with a Wheatstone Bridge, and stream flow was measured with a pygmy current meter provided by the U. S. Geological Survey.

The presence of living organisms in a stream indicates that habitat requirements have been fulfilled for the life of the organism up to the time of collection. On the other hand, chemical and physical data alone indicate the nature of the habitat only at the time of collection. Therefore, samples of plankton and fish life were taken at all stations. Collections of algae were made and preserved for future identification. The benthos, which are relatively more fixed in location in a stream and therefore are better indicators of pollution, were disappointingly few throughout most of the river system. The loose and shifting sand does not promote the establishment of many bottom organisms.

A Wisconsin plankton net with No. 25 bolting was used to secure qualitative measurements of the microfauna. The data thus gathered were reinforced with information from a study of the relative abundance of the organisms in each collection. This method of studying communities was the only means practical when one considered the number of sampling stations, the shallowness of the water, and the sandy nature of the stream bed. The plankton collections were preserved in four percent formalin and the fish specimens in ten percent formalin.

Fish were collected with a seine of one-quarter inch mesh, and the relative abundance of each fish was recorded for each collection.

Chemical Observations

Insofar as the general chemical and physical data collected at each station on a given date do not show wide fluctuations as compared with the chemical constituents originating from the brine, it seems best to summarize these data rather than to present details.

Bicarbonate alkalinity ranged from 74 to 230 p.p.m. $CaCO_3$ in Salt Creek throughout the year. These figures represent the range at all stations and the greatest range at a single station. The range in the creek on any one day was never found to be greater than 100 p.p.m.

The carbonates were usually present up to 12 p.p.m. $CaCO_3$ at all stations with the exception of Station 10 where carbonates were at times absent and carbon dioxide present up to 8 p.p.m. The pH ranged from 7.3 to 8.3.

Sulphates, which were checked on nine different occasions, ranged from 127 to 476 p.p.m. It appears that sulphates increased towards the mouth of Salt Creek. Dissolved oxygen was always above 5 p.p.m. and over 80 percent saturation.

Chlorides in Salt Creek varied from 1,749 to 19,520 p.p.m. (Fig. 2). Since the headwaters of Salt Creek received the brine, chloride concentrations were much higher in these waters and decreased downstream. The ranges of chlorides (p.p.m.) at each station throughout the year were as follows:

Station 10	15,520 to 8,623	Station 14	6,999 to 1,749
Station 12	9,912 to 3,345	Station 15	985 to 120

Brine wastes usually are relatively high in ions other than the chloride ion, namely, calcium, sodium, magnesium, and potassium. Since these determinations do not readily lend themselves to field work they were not made. However, their analyses were made December 16 (Table 1). It is assumed that the ions in question vary with respect to the chloride ion

TABLE 1.—*Chemical characteristics of water at Station 10, Salt Creek, December 16, 1951*
[Determined by U. S. Geological Survey]

pH	7.2	Magnesium (p.p.m. Mg)	274
Methyl-orange hardness (p.p.m. $CaCO_3$)	4,380	Potassium (p.p.m. K) + Sodium (p.p.m. Na)	5,700
Total hardness (p.p.m. $CaCO_3$)	4,590		
Dissolved solids (p.p.m.)	20,600	Bicarbonate (p.p.m. HCO_3)	260
Specific conductance at 25° C.(micromhos)	29,900	Sulfate (p.p.m. SO_4)	131
Specific gravity	1.013	Chloride (p.p.m. Cl)	11,800
Calcium (p.p.m. Ca)	1,390	Nitrate (p.p.m. NO_3)	4.3

although this assumption may not necessarily hold true. The importance of these ions was discussed in a previous paper (Clemens and Jones, 1955).

Specific conductance ranged from 4,800 to 42,100 micromhos at 18° C. and varied according to the chloride concentration. The minimum conductance of 4,800 micromhos at 18° C. is considerably out of the natural range suggested for the western plains area by Ellis (1937) who stated that specific conductance of a stream supporting a well developed fish fauna to be usually less than 2,000 micromhos at 25° C. The high conductance is believed to be largely due to brine wastes and not to the fact that the stream flowed through a region of gypsum deposit. Unpolluted portions of the Little Washita originating in gypsum deposits exhibited specific conductances from 1,570 to 2,070 micromhos at 18° C.

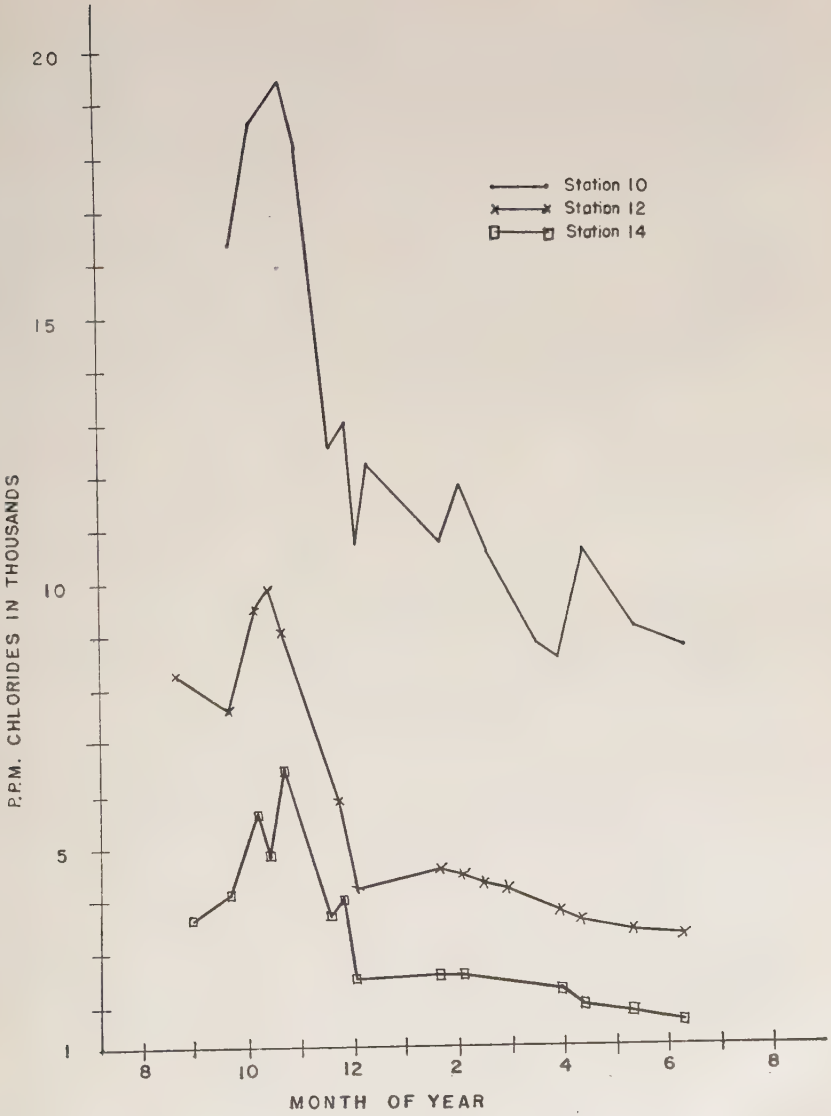

FIGURE 2.—Seasonal variation in the chloride concentration of Salt Creek from August 1951 to June 1952.

TABLE 2.—*Number of times organisms were taken at different stations along Salt Creek at varying chloride concentrations from August 1951 to June 1952*

Organism	Cl (p.p.m.) and station number																					
	0-1,000	1,000-2,000	2,001-3,000	3,001-4,000		4,001-5,000		5,001-6,000		6,001-7,000	7,001-8,000	8,001-9,000		9,001-10,000		10,001-11,000	11,001-12,000	12,001-13,000	13,001-14,000	16,001-17,000	18,001-19,000	19,001-20,000
	15	14	14	12	14	12	14	12	14	14	12	10	12	10	12	10	10	10	10	10	10	10
Euglena	9	2	5	4	2	5	3	1	1	1	1	3	1	3	1	4	1	2	1	1	2	1
Chironomidae	9	1	5	3	2	5	3	1	1	1	1	3	1	3	1	4	1	2	1	1	2	1
Nematoda	9	2	5	4	2	5	3	1	1	1	1	3	1	3	1	4	1	2	1	1	1	1
F. kansae	6	2	3	4	2	5	3	1	1	1	1	2	1	3	1	4	1	2	1	1	2	1
Cyclops	9	1	5	4	2	5	3	1	1	1	1	3	...	2	1	2	...	...	...	...	1	...
Notommata	2	...	5	2	...	4	1	1	...	...	...	2	...	...	...	3	1	2	...	...	...	...
Notholca	2	1	5	2	...	5	1	...	...	...	...	2	...	1	...	3	1	...	...	...	...	...
Monostyla	7	...	1	1	...	2	...	...	...	...	1	1	...	...	...	1	...	...	...	...	...	...
Difflugia	5	...	2	3	1	1	1	1	...	1	...	1	1	...	3	...	...	...	...	...	...	...
Dragonfly	3	1	1	3	...	1	1	...	1	...	...	...	...	...	1	...	...	...	...	...	...	...
Ceratium	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
Alona	2	1	...	1	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...
Ostracoda	...	...	...	...	1	...	2	...	1	1	1	...	...	...	2	...	...	...	...	...	...	...
N. lutrensis	8	2	5	3	2	...	2	...	1	...	1	...	1	...	...	...	...	...	...	...	...	...
P. promelas	4	...	2	2	...	...	...	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...
Cambarus	...	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
G. affinis	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
Lecane	8	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Brachionus	2	2	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cephalodella	8	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Epiphanes	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lepadella	2	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Platyias	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pedalia	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Keratella	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Daphnia	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Trichocerca	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Polyarthra	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
N. deliciosus	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
N. crysoleucas	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
P. mirabilis	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
H. placitus	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Physa	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Number of samplings	9	2	5	4	2	5	3	1	1	1	1	3	1	3	1	4	1	2	1	1	2	1
Average number of kinds	13	11	9	9		8		10		8	9	7		8		7	6	5	4	4	4	4

Biological Conditions

The community composition of Salt Creek was directly correlated with the concentration of the chloride ions. Since the chloride concentration varied at each station, the kinds of organisms were tabularized against the chloride concentration (Table 2). The stations were designated in the table according to the mark given in the legend. Thus the occurrence of each organism with respect to the chloride concentration and the station is given. Further, the times of occurrence of each organism can be obtained by referring a station and the respective chloride concentration in Table 2 to Figure 2. For instance, if we note in Table 2 that *Euglena* occurred at Station 10 when the chloride concentration was from 19,000 to 20,000 p.p.m. chloride, then in Figure 2 we see that this chloride concentration occurred at Station 10 in the last week of October and thus *Euglena* occurred at this time. This procedure applies to Station 10, 12, and 14 as the chloride concentrations are not plotted from Station 15 in Figure 2.

The average number of organisms found in chloride concentrations ranging from 13,000 to 20,000 p.p.m. was 4. This number increased to 6 for the 10,000 to 13,000 range, to 7 for the 8,000 to 10,000 range, to 8 for the 4,000 to 8,000 range to 10 for 1,000 to 4,000 range, and to 13 where the chlorides were always below 1,000 p.p.m.

The somewhat arbitrary grouping of the chlorides is applied here for practicality of presentation. The average numbers of organisms in Table 2 give some idea of the number that might be found in Salt Creek at any one time in a particular chloride concentration. The value of the estimates of course is based on the fact that day-to-day or even week-to-week changes in chloride concentrations in Salt Creek are not as radical as was believed.

The only organisms found in the 13,000 to 20,000 p.p.m. range were: *Euglena,* nematodes, chironomids, *Fundulus kansae,* and on one occasion, *Cyclops.* This range of chloride concentrations, however, hold for only collections from September 14 to October 21. Other, non-polluted stations on the Little Washita drainage had an average of 14 organisms per collection during the same period. It is realized that factors other than chloride may limit the number of organisms at this and other stations to be discussed and hence that the presence of organisms in this concentration of chloride rather is more significant than their absence.

In the 10,000 to 13,000 p.p.m. group, three rotifers—*Notommata, Notholca,* and *Monostyla*—appeared. *Notomata* and *Notholca* were most abundant during the cold-water period from November to April at a time when chloride concentrations in Salt Creek were not above 13,183 p.p.m.; it was accordingly impossible to say whether or not these forms could withstand higher concentrations. Whenever *Notommata* was found in the Little Washita drainage it was by far most numerous in Salt Creek.

Difflugia, Notropis lutrensis, Ceratium, dragonfly nymphs, *Alona,* and ostracods were collected in waters of 8,000 to 10,000 p.p.m. chloride. Only

single specimens of *Alona, Notropis lutrensis,* and *Ceratium* were found, however, which suggest that these organisms were by no means well adapted to such chloride concentrations. Ostracods appeared twice in October in relatively great numbers when the chloride concentrations were 9,097 and 9,912 p.p.m. The ostracods of this group were seasonal, occurring from August to October, and were much smaller than those found at stations where the chloride value was below 1,000 p.p.m.

Five additional forms appeared in samples of water containing 4,000 to 8,000 p.p.m. chloride: *Pimephales promelas, Gambusia affinis, Cambarus,* and two rotifers, *Brachionus* and *Lecane.* The latter two, however, were so few (one *Lecane* and two *Brachionus*) that they may lack tolerance to this chloride concentration. In fact, this single specimen of *Lecane* was the only one found throughout the entire length of Salt Creek. This observation and the fact that *Lecane* appeared in samples frequently at other stations within the Little Washita river basin, suggested that this rotifer was highly sensitive to the chloride or the accompanying ions common to brine water. Likewise, the two species of fish were represented by single specimens. There is evidence to suggest that *Gambusia* may be able to withstand higher chlorides up to 8,592 p.p.m. but the fathead minnow, *Pimephales promelas,* more likely is to be found in chloride concentrations below 4,883 p.p.m. (Clemens and Jones, 1955). We believe that there was not enough quiet water along the edges of Salt Creek to provide suitable habitat for the mosquitofish. Insofar as crayfish were not specifically sought in the field the occurrence in collections was erratic. Clemens and Jones (1955) suggested that LD50 for *Cambarus* was 17,403 p.p.m.

At stations where the chloride concentration was as high as 4,000 p.p.m., the collections included *Cephalodella, Keratella, Platyias, Lepadella, Epiphanes, Pedalia,* and *Daphnia.* The presence of only one specimen of the last four organisms probably denotes their sensitivity to the brine wastes. In fact, the specimens of *Pedalia, Keratella,* and *Daphnia* all occurred in samples where the chloride concentration was less than 2,000 p.p.m.

The organisms found at a station on the Little Washita immediately below its confluence with Salt Creek are also listed in Table 2. These organisms were present in waters with a chloride content of 120 to 985 p.p.m. The rotifers, *Trichocera* and *Polyarthra,* were collected at this station but never in Salt Creek itself. Nevertheless, the greatest difference seemed to be in the fish fauna. Four additional species of fish were taken, none of which were ever obtained within Salt Creek. These species, *Notropis deliciosus, Notemigonus crysoleucas, Phenacobius mirabilis* and *Hybognathus placita,* may have been excluded from Salt Creek by the high salt concentrations. Information available for two of the species of fish indicates that on the basis of chlorides alone they might be expected to occur in Salt Creek. Wiebe, Burr, and Faubion (1934) showed that 5,000 p.p.m. chloride killed golden shiners in 143 hours while the plains minnow, *Hybognathus placita,* has been collected by Lewis in waters containing 9,976 p.p.m. chloride. Another explanation for their absence may lie in the physical

characteristics of the stream. The water of Salt Creek was never more than a few inches deep when visited and the stream was without pools of any consequence.

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QUANTITATIVE CREEL CENSUS ON 12 MINNESOTA LAKES

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Abstract

A sampling technique is described for quantitative creel census on large lakes with numerous public access points. By use of contacts with anglers and boat counts over spaced intervals, one man, working a 5-day and 40-hour work week, can obtain an estimate of sport fishing pressure and harvest and of goodness of fishing on two lakes.

A summary and comparison of census results from the 12 lakes totalling 15,136 acres is given along with discussion of reliability of census methods. During the fishing year 1954 (December 1, 1953 to November 30, 1954) mean fishing pressure on the lakes was 36.8 hours per acre; mean harvest was 30.7 fish and 17.8 pounds of fish per acre; and mean rate of catch for summer anglers 0.83 fish and 0.47 pound of fish per hour. Fishing harvest by summer angling, winter angling, and winter spearing are compared and trends in the catch and habits of fishermen for the three years 1952–54 are described. During the 3 years of census total fishing pressure and harvest on the lakes appear to have increased about 15 percent but goodness of fishing has remained nearly constant.

Introduction

Creel census has been fairly common in fishery research on fresh waters. Such censuses usually have been made as "spot checks" to determine angling success as fish taken per man-hour of fishing, or to estimate total yield of small lakes that have few points of access. Often the censuses have been of short duration and methods used applicable only to the special situation at hand.

In Minnesota in 1951 the need arose for quantitative creel census of annual sport-fishing pressure and harvest that could be applied to representative series of large Minnesota lakes with numerous points of public access. The present paper deals with the development of census methods during the 3 years 1952–1954 and with some of the results obtained. Emphasis will be placed on the principles rather than on the details of the "biological bookkeeping."

Nature of the Problem

Before the statement on goals and discussion of methods, it is necessary to consider briefly the more important aspects of Minnesota sport fishing. Lakes are fished both summer and winter. Summer anglers fish from both boat and shore with a considerable variety of fishing methods. Trolling with an outboard motor is permitted and during the years 1953 and 1954

angling with two lines was allowed for pan fish and rough fish. Winter fishing, usually begins about December 15 and, except for pan and rough fish, ceases on February 16. Winter fishing is of two types—angling through the ice either in the open or from a shelter and spearing from a "darkhouse," that is, a windowless shelter. Winter angling usually consists of fishing with a drop-line with minnows as bait and is directed principally at crappies. Spearing is limited by law to northern pike and non-game fish of which whitefish is the species most commonly taken. The general open-water angling season extends from about May 15 to ice formation on the lakes; usually about December 1. Black bass and trout have shorter seasons.

Little fishing is done between October 15 and December 15 and between February 15 and April 15. To include a complete summer and a complete winter fishing season in each census year, the fishing year is defined as extending from December 1 of one year to November 30 of the next. The year is designated according to the included summer angling season.

The location and size of the 12 lakes censused in 1952–1954 shown in Table 2. All are fairly large, ranging from 312 to 5,111 acres and having a total area of 15,136 acres. These lakes are accessible at many points and some of them have numerous cottages and resorts. They were chosen in pairs, 2 lakes in each of 6 Fisheries Districts, and were selected on the basis of; (1) representativeness of fishing lakes; (2) proximity to the Fisheries Headquarters; and (3) nearness to each other to reduce driving by the creel-census personnel.

During the first year of the census, 1952, the work was done by state fishery personnel and during 1953 and 1954 by six biologists employed with aid of Dingell-Johnson funds. Each biologist was assigned two lakes. In addition, one man (the junior author) supervised the project and his aide served as relief man for the census biologists.

Goal of the Census

The plan for the census called for the collection of following information from the 12 lakes:

1. Annual catch of fish, total and by species, from each lake expressed both in numbers and pounds. This harvest was also calculated as yield per acre of water.
2. Distribution of take by species, by fishing seasons and types of fishing, that is, summer angling, winter angling, and winter spearing.
3. Catch per unit of effort for combined catch and individual species for the year, fishing seasons, and types of fishing—expressed as numbers and pounds per man-hour and trip.
4. Comparative catch of summer fishermen using different fishing methods.
5. Fishing pressure as hours per acre—total for the year and by seasons and methods.

To get the data desired it was necessary to:

1. Estimate the number of fisherman-trips on each lake each census day.
2. Obtain from anglers the average catch of fishermen expressed as numbers and pounds of fish.

3. Learn from anglers the average length of fishing trips in hours.
4. Obtain information from fishermen contacted on method or goal of fishing.

From these data estimates of catch and fishing pressure were calculated.

Operational Limitations

Because one field man is responsible for the census of two lakes and because each lake has many points of public access, the census had to be of a sampling type. The principal problems were the design of adequate and representative sampling procedures and adjustment of these procedures to the manpower available and work schedules.

The sampling pattern evolved during the 3 years is designed to allow a man on a 40-hour, 5-day work week to census two lakes with as little overtime as possible and to permit this employee two successive days of leave in most weeks.

The census plan is also designed so that the fishermen contacts and boat and angler counts on the lake could be made at not more than three places and preferably from one contact point. Each census biologist had his own car and was supplied with a boat, outboard motor, a spring scale, binocular, and other miscellaneous equipment.

Census Pattern and Methods

Selection of census days.—The first phase of planning the sampling procedure involved selection of days for census. It was known from previous work that week days and week-end days had to be considered separately in sampling because of the heavier fishing pressure on week-ends. Holidays were considered as week-end days. The census on week-end days presented no special problem since the Saturdays and Sundays could be alternated. Several plans were tried, however, for sampling week days before the final pattern was evolved.

During the first year, 1952, each lake was censused 1 week day and 1 week-end day each week. The week-end days were alternated and the week days rotated in regular succession. This schedule resulted in contact with about 7 percent of the anglers estimated to be present. During the next year, 1953, the number of census days was increased to 3 per week—2 week days and 1 week-end day. Week-end days were alternated and week days rotated as before with 1 non-census day between the 2 week days censused. Thus a lake might be censused on Monday and Wednesday the first week, Tuesday and Thursday the second week, ... Under this plan, contacts with anglers in summer rose to 15 percent but some adjustment of schedule was necessary in the field because this pattern sometimes resulted in the same day being scheduled for census on both lakes. Also, the scheduling of 6 work days per week was in conflict with the prescribed 5-day work week for state employees.

It became apparent also that the 1953 schedule of census days when used with a short summary period of 4 weeks created some bias in the cal-

culated results. The day-to-day distribution of fishing on week days varies in different parts of the state; it is relatively lighter in mid-week in the vicinity of metropolitan areas than it is in resort districts where anglers are in residence. A better census pattern is one that allows each week day to be censused an equal number of times during the census period. To accomplish this balance a longer rotation period was necessary. The period between summaries was therefore lengthened from 4 to 10 weeks; then each week day was censused three times and given equal emphasis. Spacing of census days in 1954 is shown in Table 1.

TABLE 1.—*Census schedule for lakes "A" and "B" for 10-week census period*

Serial number or week	Day of week						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	A	...	...	B	A	B	A
2	B	A	...	...	B	A	B
3	A	B	A	...	...	B	A
4	B	A	B	A	...	...	B
5	A	...	A	B	A	...	A
6	B	...	...	A	B	A	B
7	A	B	...	...	A	B	A
8	B	A	B	...	...	A	B
9	A	B	A	B	...	...	A
10	B	...	B	A	B	...	B

With the census pattern shown in Table 1, 15 census days are scheduled each week, the 3 week days are scheduled without conflict between the two lakes, and 2 successive days of leave are provided for census personnel in 4 weeks out of 5.

Selection of census hours.—Because of its latitude, Minnesota has as many as 14 daylight fishing hours each day during much of the summer. Since the 40-hour work week must be divided between two lakes, certain periods of the day must be selected and the data from the missing portions of the day estimated. The following methods were used.

In 1952 "long" census days of 14 hours were separated by two "short" days of 8 hours; this plan fitted into the rotation of week and week-end days on each lake. The 8 hours of the "short" day were in that part of the day when fishing was heaviest. In the final calculation, data from each "short" day were expanded in amount equivalent to the average proportion of the catch and pressure recorded for the other 6 hours of 14-hour days during the month for which the summary was made.

During the next year, 1953, a similar plan was followed except that 1 "long" day was followed by 3 "short" days to reduce the number of man-hours required. Estimates were made as in 1952.

The pattern of "short" and "long" day has two weaknesses. First, bias is introduced by placing emphasis on heavily fished portion of the "short" day. Second, adverse or very favorable conditions affecting fishing on the "long" day might have undue influence on the calculation of total yield and pressure for the "short" days.

To eliminate these defects a different type of census-period schedule was used in 1954. All census days were made 8 hours long. Days extending from 7:00 a.m. to 3:00 p.m. were alternated with census days extending from 11:00 a.m. to nightfall. At the end of the census period the date for the missing portion of each day were estimated on the basis of records for the overlapping hours, 11:00 a.m. to 3:00 p.m. during the 10-week period.

For example, on May 4 a lake is censused from 11:00 a.m. until dark; boat counts show 82 boats on the lake during this period of which 12 were tallied between 11:00 a.m. and 3:00 p.m. and the rest between 3:00 and dusk. To complete the estimated boat count for the day an estimate of boats for the missing period of 7:00 a.m. to 11:00 a.m. must be made.

At the end of the 10-week census period it is found that, on the average, 60 percent of the boats counted during the morning census period were seen between 11:00 a.m. and 3:00 p.m.; the remaining 40 percent were counted earlier in the morning. Therefore, the best estimate of the missing period of the May 4 would be represented by that number of which 12 boats (the number counted between 11:00 a.m. and 3:00 p.m.) represent 60 percent. The total estimated count for May 4 is therefore:

$$70 + \frac{1{,}200}{60} = 90$$

It should be pointed out that the percentage factor (such as the 60 percent used above) will be different for calculating missing counts at the other end of the day.

Counts of Boats and Anglers.—During the census periods it is necessary to obtain an estimate of the number of anglers fishing on the lake. Since most Minnesota anglers fish from boats such a tally requires a count of boats plus a count of the smaller number of shore anglers. A figure for average number of anglers per boat is also necessary so that boat counts can be expressed as angler trips.

The lakes censused have so many points of access that it is not possible for one man to tally all boats at the end of the fishing trip. To count them an interval-count method was devised whereby all boats and shore anglers on the lake were counted with the aid of binoculars every 2 hours. Time intervals for the counts were the odd-numbered hours, because the majority of afternoon and evening fishermen in summer quit fishing around 5:00 p.m., 7:00 p.m., or 9:00 p.m.

From these interval counts the approximate total number of boat trips for the census period was calculated by totalling the numbers of boats counted on the count intervals (9:00 a.m., 11:00 a.m., . . .) and then multiplying this total by the fraction expressing length of interval count in hours divided by the average length of boat trip for the day as determined from angler contacts. This method is shown graphically in Figure 1.

In the figure the eight short horizontal lines represent boat trips ranging in length from 2 to 4 hours with a mean length of 3 hours. Vertical lines represent the 2-hour interval counts on the odd-numbered hours. Boat counts are represented by intersections of lines.

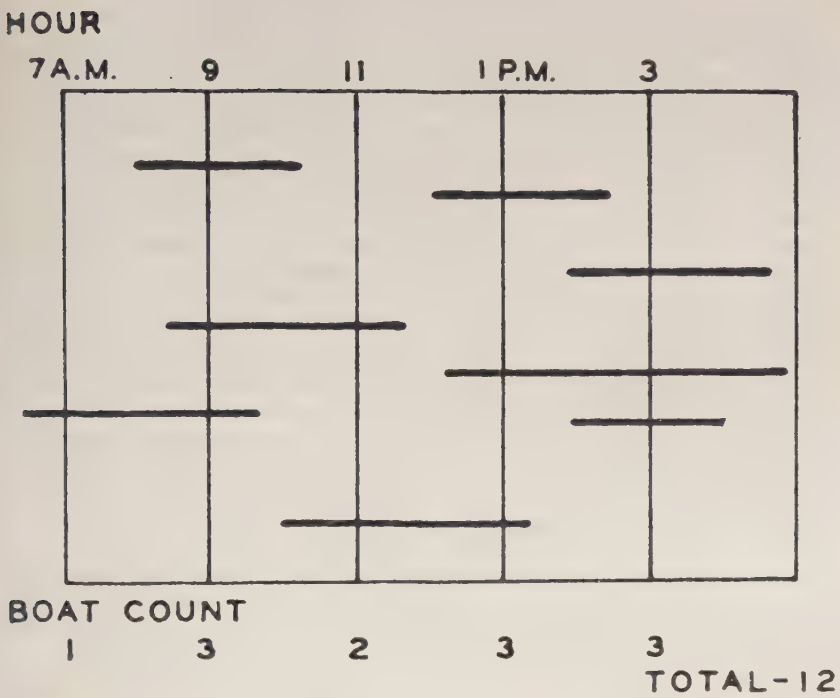

FIGURE 1.—Graphic representation of method for estimation of total boat trips for census period from interval counts.

Because some boats were counted once and some twice, the total interval count cannot be used as a direct expression of number of boats present. However, the average length of boat trip is known from interviews with fishermen—in this case 3.0 hours. The most likely number of boats present during the census period can therefore be estimated by multiplying the total of the interval counts (12) by the count interval (2 hours) over the average length of trip (3 hours) or 2/3. Two-thirds of 12 is 8 which is the number of trips shown on the graph.

This method can be regarded as fairly accurate if (1) the length of boat trip is longer than the interval between counts; (2) enough fishermen are contacted to obtain a valid figure for mean length of trip; and (3) if all boats on the lake can be seen and counted. The method was used also to obtain an estimate of the number of shore anglers, who made up about 7 percent of the total angling population, but the results for them are too low since the average length of trip of shore anglers is only 1.4 hours and some were missed by interval counts. It was not thought desirable, however, to reduce the counts to 1-hour intervals to gain additional accuracy since the time could be better spent in obtaining a greater number of angler contacts.

Methods for Censusing Winter Angling and Spearing.—The methods used for censusing winter angling and spearing, with two exceptions, are generally similar to those described for summer angling. Field contact with dark-house spearers is done by attaching a tally card and pencil to the door of the dark house. The spearer recorded his own catch and effort when he had finished spearing. This method was devised because it is usually not possible to determine from the lake shore whether or not a dark house is occupied. In winter, because of the shortness of the day, it is not necessary to break the census pattern into morning and afternoon hours. The short day made complete census of the entire day possible.

Form and Calculations.—Quantitative creel census requires detailed and continuous bookkeeping and uniform methods of calculation. During the present census five forms were used; (1) field tally sheet for recording data from anglers contacted, (2) boat-and-angler-count tally sheet; (3) summary sheet for compiling and computing fishing effort and total catch for each 10-week period; (4) summary sheet for compiling and computing take of individual species of fish during the 10-week period; and (5) special summary sheet for winter spearing. Samples of these sheets with instruction for use will be sent any reader on request.

At the end of the 10-week census period data from the period are expanded to totals for the census days by methods already described and estimates of catch and pressure for non-census days are made on the basis of average catch and pressure for censused days during the 10-week period. Separate calculations are made for week and weekend days.

Results of Census

The 1954 Census.—In the summary of the data for 1954 (Table 3) considerable differences in fishing pressure will be noted for the 12 lakes—from 4.7 fishing hours per acre for Ball Club, a large wilderness lake with a population principally of northern pike, to 115.7 hours per acre for Bald Eagle, a heavily fished northern pike and centrarchid lake near St. Paul. Mean fishing pressure for all 12 lakes was estimated to be 36.8 hours per acre.

The average annual sport-fishing harvest from this series of lakes was estimated to be 30.7 fish and 17.8 pounds per acre. The range in yield for the individual lakes was 4.1 to 70.4 pounds per acre.

Fishing success averaged 0.83 fish and 0.47 pounds of fish per hour for summer anglers; 1.06 fish and 0.46 pound of fish for winter anglers and 0.25 fish and 0.73 pound for winter spearers. As previously noted, the summer angling catch was fairly well distributed over the entire game-fish population but the winter angling catch was largely of crappies; and winter spearing take, because of legal restrictions, was mostly of northern pike. Mean percentage composition of the total catch from the 12 lakes by the three fishing methods in 1954 is shown in Table 3.

In 1954, 76.7 percent of the total harvest by weight was taken by summer angling, 14.7 percent by winter angling, and 8.6 percent by spearing.

TABLE 2.—*Fish harvest from 12 Minnesota lakes for the fishing year December 1, 1953, to December 1, 1954*

[Lakes starred (*) had a fishing harvest principally of walleye; in Ball Club the take was principally of northern pike. In the other lakes centrarchids, especially sunfish and crappies, predominated in the catch]

Lake	County	Area (acres)	Total fishing trips	Fishing pressure (hours per acre)	Catch per acre of water							
					Winter angling		Spearing		Summer angling		All fishing	
					Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
Bald Eagle	Ramsey	1,055	40,305	115.7	16.3	8.2	0.3	1.2	66.2	27.6	82.8	36.1
Linwood	Anoka	766	22,463	96.2	49.2	14.8	0.8	2.8	36.3	18.5	86.3	36.1
Francis	Le Sueur	898	32,614	113.9	13.2	7.0	1.3	3.0	90.7	37.1	105.2	47.1
Clear	Le Sueur	312	7,734	73.7	24.3	12.1	0.4	2.2	96.9	56.1	121.6	70.4
Maple	Douglas	825	12,425	36.5	8.4	3.9	0.5	1.2	44.2	22.9	53.1	28.0
Grove	Pope	461	5,586	31.5	....	....	1.9	4.3	11.7	11.5	13.6	15.8
*Little Pine	Ottertail	2,113	14,995	20.5	....	....	0.9	1.6	7.7	6.6	8.6	8.2
*Sallie	Becker	1,262	13,884	37.0	3.3	2.6	0.3	1.0	18.6	20.0	22.2	23.6
Ball Club	Itasca	5,111	7,660	4.7	....	....	0.4	1.4	1.2	2.7	1.6	4.1
*Moose	Itasca	1,199	8,451	16.7	....	....	....	....	3.6	5.2	3.6	5.2
Gladstone	Crow Wing	481	10,010	51.5	2.3	0.7	0.3	1.4	73.5	30.0	76.1	32.1
Nokay	Crow Wing	655	11,815	48.6	7.3	3.8	0.4	1.1	45.6	22.5	53.3	27.4
Total or average		15,136	187,942	36.8	6.0	2.6	0.5	1.5	24.2	13.6	30.7	17.8

In the total catch for the year, all methods combined, sunfish ranked first in terms of numbers of fish caught (34.7 percent), followed by crappies (30.9 percent), others (20.4 percent), northern pike (6.9 percent), walleyes (4.6 percent), and black bass (2.5 percent). In terms of weight the percentages were: northern pike, 28.2; crappies, 22.2; sunfish, 20.0; others 14.5; walleyes, 10.8, and black bass, 4.2.

In the individual lakes (Table 1) the four from which the take was principally of larger predaceous fishes, especially walleyes and northern pike

TABLE 3.—*Percentage composition of sport-fishing harvest from 12 Minnesota lakes in 1954*

Species	Summer Angling		Winter Angling		Spearing	
	By weight	By number	By weight	By number	By weight	By number
Northern pike	24.8	6.4	11.0	2.1	88.3	81.8
Walleye	13.7	5.8	2.0	0.5	....	....
Sunfish	25.3	42.5	4.5	6.2	....	....
Crappies	13.4	17.9	80.5	86.0	....	....
Black bass	5.2	1.8	....	....	....	....
Others	19.8	25.5	2.0	5.3	11.7	18.2

(Ball Club, Sally Moose, and Little Pine) had comparatively low total yields (from 4.1 to 23.6 pounds per acre; with an average of 10.2 pounds per acre). The highest yield was from Clear Lake where the centrarchid harvest was augmented by a considerable take of rough fish, especially bullheads. Both quality and quantity of fishing must be considered in lake management and a total production probably will be low if the catch includes a high proportion of the more desired predaceous fishes.

The census also throws light on fishing habits. Summer anglers who fished from boats were on the lake an average of 3.0 hours per trip while shore anglers, averaged only 1.4 hours per trip. Winter anglers fished an average of 3.1 hours per trip while spearers, who mostly fished from heated fishing houses, had an average trip length of 3.6 hours.

In general, fishing pressure on a lake was directed principally at the most abundant species of desirable fish and the fishing methods were usually designed to take such species. Thus, on walleye lakes anglers fished primarily for walleyes and on centrarchid lakes they fished principally for centrarchids. However, there was always a large group of inexperienced anglers who were "just fishing." In an attempt to determine the success of various fishing methods the anglers were separated into: "gamefish" fishermen, who were avowedly fishing for walleyes, northern pike, and black bass; "panfish" fishermen who said they were fishing for sunfish, crappies, or rock bass, and "mixed" fishermen who were fishing for other species or for both "panfish" and "game fish." Of the total catch by summer angling in 1954, 81.8 percent of the "game" fish taken were taken by "game fish" fishermen, and 86.4 percent of the "panfish" were taken by "panfish" fishermen.

Comparison of Three Years of Census.—In a sampling census of the

kind described, the estimated catch and fishing pressure represent parameters whose exact size is unknown. It is therefore of interest to compare data gathered from the same lakes over the 3-year period and to comment on variations of estimate. Comparative data for 1952, 1953, and 1954 are shown on Table 4.

TABLE 4.—*Comparison of creel census on 12 lakes for fishing years 1952, 1953, and 1954*

Item	1952		1953		1954	
Fishing pressure (hours per acre)						
Winter angling	2.8		4.6		5.7	
Spearing	1.0		1.6		2.1	
Summer angling	26.3		27.3		29.0	
Total	30.1		33.5		36.8	
Length of fishing season (days)						
Winter angling (effective)	58		77		94	
Spearing (legal)	41		65		66	
Summer Angling (effective)	152		169		168	
	Number	Pounds	Number	Pounds	Number	Pounds
Yield per acre per year						
Winter angling	3.2	1.3	4.4	2.1	6.0	2.6
Spearing	0.2	0.6	0.5	1.2	0.5	1.5
Summer angling	23.8	13.5	22.9	12.9	24.2	13.6
Total	27.2	15.4	27.8	16.2	30.7	17.8
Percentage of total catch by seasons						
Winter angling	11.8	8.4	15.7	13.1	19.6	14.7
Spearing	0.8	3.9	1.5	7.1	1.7	8.6
Summer angling	87.8	87.7	82.8	79.8	78.7	76.7
Fishing success per hour						
Winter angling	1.12	0.46	0.99	0.46	1.06	0.46
Spearing	0.22	0.60	0.26	0.70	0.25	0.73
Summer angling	0.90	0.51	0.84	0.47	0.83	0.47

The figures for estimated average fishing pressure, harvest, and take per man-hour are similar for the 3 years, but there is apparently an upward trend of about 15 percent in pressure and total catch. Much of this trend can be attributed to increased popularity of winter fishing; summer angling showing only a slight increase. The growing popularity of winter fishing is also evidenced by the rise in the sale of darkhouse licenses—34,699 in 1951, 47,667 in 1952, and 61,686 in 1954. The sale of imported meal worms or "golden grubs" at bait shops also has popularized winter angling for bluegills. Increased spearing pressure on northern pike on the census lakes has caused the proportion of the total poundage of northern pike taken by spearing to rise from 8.2 percent in 1852 to 26.8 percent in 1942

The slight upward trend in summer angling pressure from 26.3 hours per acre in 1852 to 27.3 hours in 1953 and 29.0 hours in 1954 probably reflects the general upward trend in angling license sales (from 1,242,748 in 1951 to 1,291,808 in 1953), legalization of year-round fishing for panfish and rough fish in 1953–54, legalization of fishing with two lines for

pan and rough fish for these same two years, and slightly longer legal or effective fishing seasons in 1953 and 1954 (see Table 3). Any appreciable increase in the catch as a result of two-line fishing, appears doubtful, however. In 1952, a one-line year, the take of crappies and sunfishes from the 12 lakes totalled 100,000 pounds and in the following two-line years the figures were 99,000 and 113,000 pounds.

Despite an upward trend shown in fishing pressure and total catch, fishing success as catch per man-hour has remained nearly constant over the three years. Neither has any marked change taken place in the composition of the catch over the three years other than a decline in the take of northern pike, which became apparent in the summer of 1954 and which can be attributed largely to poor spawning conditions for the species in 1950 and 1951.

All in all the similarity of statistics gathered from the 12 lakes over the three years and the apparent validation of observed trends from other sources suggest that the census methods described are adequate on large lakes for supplying estimates of sport-fishing pressure and harvest that are comparable from year to year. In addition, the method is comparatively sparing of manpower and costs. One man can census two large lakes on a 40-hour and 5-day week schedule.

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MOVEMENT OF STREAM FISHES IN MISSOURI

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Abstract

Eight hundred forty-six reports of tagged fish caught by anglers were analyzed to determine the movement patterns of 14 species of native warm-water stream fishes. Each species included a sedentary group which remained near the release point and a mobile group which ranged more or less freely. The species could be classified according to the relative abundance of the two groups. Rock bass, smallmouth bass, longear sunfish, spotted bass, and yellow bullhead were classified as sedentary species; carp, flathead catfish, largemouth bass, golden redhorse, and black redhorse are semi-mobile; and channel catfish, freshwater drum, and white crappie as mobile.

The species varied greatly in the average number of days between tagging and recapture and in the direction of movement and distances traveled by the mobile fish. The mobile group usually was free longer than the sedentary fish but frequently the difference in time was not great. Mobile freshwater drum, golden redhorse, black redhorse, spotted bass, largemouth bass, and longear sunfish tended to travel relatively long distances downstream and much shorter distances upstream. The distances traveled by the remaining species were more nearly equal but the average distance traveled upstream was always the longer. Mobile yellow bullhead, green sunfish, spotted bass, longear sunfish, and largemouth bass seldom traveled more than 25 miles but some mobile carp moved over 200 miles. Other species traveled intermediate distances.

When released in headwaters, sedentary species tended to be more sedentary, and semi-mobile species in their preferred habitat also tended to be more sedentary than the average. Mobile spcies and semi-mobile species not in their preferred habitat became more mobile. Most of the mobile fish released in headwaters moved downstream.

For the four most numerous species (rock bass, channel catfish, carp, smallmouth bass) data are presented to show the effect of release location, season, and age upon movement. Rock bass were more sedentary in headwaters than farther downstream but channel catfish were more mobile in headwaters. Mobile fish of both species tended to move downstream when released in headwaters but to make more upstream movements when released in down stream areas. Carp seemed to adapt their movements to the physical conditions in the habitat. They were mostly sedentary in stable habitats but predominantly mobile in habitats subject to flooding. The subspecies of the fish, the type of stream, and the geographical location of the release site may have effected the amount and direction of movements of smallmouth bass. All four species showed a relatively high proportion of mobile fish in the spring and low proportions in the summer. Data on fall movements were not conclusive. Rock bass, channel catfish, and smallmouth bass of intermediate age were more mobile than either the younger or the older fish.

The concept that the native population of warm-water stream fish species consists of a sedentary and a mobile group provides a logical explanation of many observed phenomena and of contradictory results which have confused some investigators. It supplements recent findings concerning the home ranges of species if it is assumed that only the sedentary group was investigated.

Inland fishermen seem to have adopted the concept that warm-water stream fishes are migratory, perhaps as a result of what they have heard about certain anadromous species. "Runs" of various species are frequently reported, dams that might prevent migration are blamed for poor fishing, floods which will allow the fish to "come up" are believed a requisite for good fishing. Sport writers frequently refer to these ideas; the policies of some fishery-management agencies give evidence of their influence. Factual information on the movements of warm-water stream fishes is not abundant and the results of the studies of the problem have not received wide publicity. Many studies have been made of the movements of important commercial species, such as sardines and salmon, and of outstanding sport species, such as the trouts. The knowledge gained has made it possible to manage the fisheries more intelligently. This study, initiated to learn more about the nature and extent of the movements made by native warm-water stream fishes, is based on the analysis of anglers' reports of tagged fish caught.

Few studies have been made of the movement of warm-water fishes in streams. Furthermore, the various workers have interpreted their findings in different ways to produce an interesting variety of results. Thompson (1933) concluded that fish move in a random manner in Illinois waters, though at different rates for different species. He developed theoretical "migration constants" for the species he studied. Wickliff (1933, 1938) concluded that smallmouth bass, largemouth bass, channel catfish, rock bass, bullheads, and carp tended to move downstream in Ohio waters. Since the fish he studied came originally from lakes and were transplanted to the streams, they may not have behaved in a manner typical of native stream fishes. The experiments of Seaman (1948) with channel catfish in West Virginia streams employed methods similar to those of Wickliff and led to similar results.

Observations on native stream species usually have led to the conclusion that they move about very little. Bangham (1937) and Bangham and Bennington (1939) expressed this view for the rock bass, smallmouth bass, green sunfish, and redhorse sucker (*Moxostoma aureoleum*) in certain small Ohio streams. Similar conclusions were reached by Scott (1949) for the rock bass of Tippecanoe River, Indiana, by Tate (1949) for the smallmouth bass of small streams in northeastern Iowa, and by Harrison (1953) for the channel catfish of the Des Moines River, Iowa.

Gerking (1950, 1953) and Larimore (1952) carried the idea of limited movement a step further and concluded that native stream fishes have definite home ranges. They performed careful experiments and presented convincing evidence in support of this concept. Gerking estimated the home range of longear sunfish, rock bass, and green sunfish in small streams in Indiana to be 100-200 feet. Home ranges of smallmouth bass, spotted bass, golden redhorse, and hog sucker were estimated to be 200-400 feet. Larimore in his study of the smallmouth bass of Jordan Creek, Illinois, found that 80 percent of the marked fish recaptured during the summer in

which they were marked and 67 percent of those recaptured the next summer were in the stream section (0.11 to 0.42 mile) where they were released. Sixty percent of the tagged bass recovered were in the same pools at which they had been tagged.

These investigations (except those reported by Wickliff and Seaman) are similar in that all or a substantial part of the recaptured fish were obtained by the investigator's own efforts. Larimore sampled the entire length of Jordan Creek believed capable of supporting smallmouth bass, but did not obtain recaptures from the other streams in the drainage area. Gerking did some sampling elsewhere on the streams he studied but most of his effort was limited to small areas under intensive observation. The same was true of the work of Bangham and Bennington. From the recaptures taken in his traps, Scott concluded that it would be very unlikely that an individual rock bass would range through more than a mile of stream in the course of 2 years. He observed, however, that a few tagged fish recovered by fishermen showed much wider dispersal. Thompson and Harrison included records from recaptures by fishermen but did not distinguish between these data and those obtained by their own efforts which probably were concentrated in limited areas.

If most of the sampling is done in limited areas near release sites a strong bias in favor of restricted movement is introduced. To determine the direction and extent of the movements of marked fish, all of the water accessible to them should be sampled with equal intensity. This broad sampling is impossible under most conditions, of course, but the bias introduced by concentrated sampling in limited areas may be overcome to some extent by the use of returns obtained from anglers. Fishing pressure is not, of course, distributed uniformly over the entire length of a stream; rather it is sure to be concentrated at the more accessible areas and at well known "fishing holes." These concentrations of fishing, however, are more widely distributed than the usual sampling areas of a fishery investigator.

The use of records from anglers has other limitations. The number of returns is certain to be low. Wide publicity will overcome this limitation to some extent, but large numbers of fish must be tagged to ensure a satisfactory number of returns. The completeness and accuracy of the records obtained vary widely. This difficulty makes it necessary to exercise great care in selecting material to be used and in the interpretation of results.

Procedures

Since 1947 some 70,000 fish have been tagged and released in Missouri streams. To date, approximately 1,000 returns of 39 species have been received from fishermen. This report is based upon 846 usable returns from the 14 most numerous species (Table 1).

Most of the fish were captured originally in our stream inventory and were released at regularly established stations which were sampled three times each year. Many tagged fish were recaptured during the inventory

TABLE 1—*Total number of returns by species and classification as to types of movement*

Species	Total number	Percentage making no movements	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Rock bass, *Ambloplites rupestris*	231	64.1	18.2	16.9	0.9
Channel catfish, *Ictalurus punctatus*	184	37.0	33.2	21.2	8.7
Carp, *Cyprinus carpio*	115	51.3	25.2	15.7	7.8
Smallmouth bass, *Micropterus dolomieui*	109	63.3	20.2	15.6	0.9
Green sunfish, *Lepomis cyanellus*	45	77.8	13.3	8.9	...
Flathead catfish, *Pilodictis olivaris*	143	51.6	13.3	32.6	...
Longear sunfish, *Lepomis megalotis*	30	70.0	10.0	20.0	...
Largemouth bass, *Micropterus salmoides*	25	48.0	28.0	24.0	...
Spotted bass, *Micropterus punctulatus*	24	91.7	4.2	4.2	...
Golden redhorse, *Moxostoma erythrurum*	19	47.4	15.8	31.6	5.3
Black redhorse, *Moxostoma duquesnii*	15	60.0	20.0	20.0	...
Freshwater drum, *Aplodinotus grunniens*	11	36.4	27.3	36.4	...
White crappie, *Pomoxis annularis*	10	30.0	50.0	20.0	...
Yellow bullhead, *Ameiurus natalis*	10	80.0	20.0	....	...

[1]One fish (2.3 percent) moved 1 mile but the direction of movement was not recorded

operations but they are not included here. For the reasons discussed previously, only the returns by fishermen are used in this report.

The usefulness of records from fishermen's reports varied greatly. In our publicity releases we asked them to report the tag number, the locality and date of the catch, and the length and weight of the fish. After study of the reports, it was decided that if the locality could be established with an accuracy of 1 mile the record would be used. Thus, travel of less than 1 mile is recorded as "no movement" and greater distances are accurate within ½ mile. Most of the distances were determined with a Dietzgen map measurer on county highway maps with a scale of 2 miles to the inch. When the movement was outside the state maps of a smaller scale had to be used. Since we were more concerned with the distance the fish had traveled than with the length of time it had been free, reports on which the date was indefinite were included. For these fish the time computed was listed in the records as approximate. When the locality or date was not definite, the fisherman was requested by mail to give more detailed information. This correspondence helped to complete many of the records. The reports of lengths and weight were so often omitted and, when included, obviously varied so much in accuracy, that they have not been used.

As in other tagging studies, it has been assumed that the behavior of tagged fish is similar to that of untagged fish, but no test for this hypothesis has been devised.

Pattern of Movement

Fish are seldom still. For the purpose of this paper, however, two types of movements may be defined. The first are the more or less random movements made within a limited area. The second are those movements which result in travel through a considerable length of stream. It is the latter

type which concern us here. It is recognized that the two types can be distinguished only arbitrarily.

Amount of movement.—It is apparent from Table 1, that each species included a group of fish that remained within a mile of the point of release (*i.e.,* made "no movement") and another group which ranged more or less freely. These two groups are termed the "sedentary" and the "mobile" segments of the population. The word "mobile" is used in preference to "migratory" since there is no evidence that this segment of the population undertook mass movements, that the movements had a definite direction, or that this segment was in a distinct life-history stage. At least one of these conditions usually is true of anadromous or catadromous fishes or other animals or birds commonly described as migratory. The percentages of the total populations that belonged to the sedentary and mobile groups varied considerably among the several species. Of course, the accuracy of the percentages probably decreases with the decrease in size of the sample but the results for the more numerous species should be dependable.

These percentages seem to justify classification of the 14 species according to the relative abundance of the sedentary and mobile groups. The species in which the sedentary group was clearly predominant (rock bass, smallmouth bass, longear sunfish, spotted bass, and yellow bullhead) are referred to as "sedentary." Those species in which the mobile group was clearly most abundant (channel catfish, freshwater drum, and white crappie) are called "mobile." In an intermediate position are the carp, flathead catfish, largemouth bass, golden redhorse, and black redhorse. Approximately equal numbers of each were in the sedentary and the mobile groups. They are classed as "semi-mobile species." Some question existed as to whether the black redhorse should be classified as semi-mobile or sedentary. Since, however, the number of returns was small and it seems unlikely that the habits of this species differ greatly from those of the golden redhorse, the above arrangement was followed.

Direction of movement.—The mobile group of each species could move either upstream, downstream, or make complex movements. The latter are movements in which a fish traveled down one stream and then up another. Since complex movements begin as downstream movements, they are included with the downstream movements in a preliminary analysis of the direction of travel. The different species exhibited marked differences in the proportions of mobile fish traveling upstream and downstream. The numbers of rock bass, channel catfish, carp, largemouth bass, spotted bass, and black redhorse that moved in each direction were nearly equal. Smallmouth bass, green sunfish, white crappie, and yellow bullhead showed a greater tendency to move upstream, and flathead catfish, longear sunfish, golden redhorse, and freshwater drum tended to move downstream. This matter is discussed in more detail in a later section.

Time free and distance traveled.—The average number of days between tagging and recapture varied greatly among the species (Table 2). Some,

such as the white crappie, the two redhorses, and the green sunfish, were free a relatively short time whereas others, notably the carp and flathead catfish, were free relatively long periods of time. A number of factors could contribute to this difference. Some of the most obvious are the longevity of the species, the intensity of the fishery, and the ability of the species to survive handling and retain tags. The later factor is considered especially important.

TABLE 2.—*Average number of days free by species for fish that made no movement and average days free and miles traveled for fish that made various types of movements*

Species	No movem't	Upstream		Downstream		Complex movement	
	Average days free	Average days free	Average miles traveled	Average days free	Average miles traveled	Average days free	Average miles traveled
Rock bass	148.8	209.2	9.1	143.1	6.1	216.0	144.0
Channel catfish	185.5	223.2	14.8	309.1	11.9	314.8	46.1
Carp	385.7	327.4	11.7	395.2	7.9	582.2	101.0
Smallmouth bass	157.3	234.2	7.3	176.6	4.9	118.0	121.0
Green sunfish	75.9	136.2	5.7	97.5	3.3	.....	.....
Flathead catfish[1]	308.9	308.2	16.5	340.7	12.5	.....	.....
Longear sunfish	141.3	191.3	4.3	227.5	10.7	.....	.....
Largemouth bass	114.6	127.4	6.4	290.7	11.8	.....	.....
Spotted bass	183.5	180.0	7.0	129.0	24.0	.....	.....
Golden redhorse	68.4	174.0	7.6	154.0	34.2	199.0	53.0
Black redhorse	34.3	148.0	7.0	90.7	25.3	.....	.....
Freshwater drum	162.3	351.3	12.0	317.5	65.3	.....	.....
White crappie	11.0	91.0	25.4	26.5	20.5	.....	.....
Yellow bullhead	212.4	75.5	4.5	.....	.....	.....	.....

[1]One free 721 days moved 1 mile. Direction not reported.

Usually, the mobile group of a species was free longer than the sedentary group. Exceptions occurred, however, and for several species the difference in time was small. If, as Thompson maintained, fish movements were random and the distance a fish traveled were limited only by the length of time it had been free, we should expect the mobile group to have been free much longer than the sedentary group. Time obviously is a factor in fish movement as in any kind of travel. It is not surprising that the fish which moved had been free for a relatively long time but that those showing no movement were free nearly as long. The existence within each species of a sedentary group which tends to remain in one place and of a mobile group which tends to travel would seem to explain best the data presented here.

The average distance that mobile fish traveled upstream and downstream differed rather widely among the various species. They fall into two well defined groups. Freshwater drum, golden redhorse, black redhorse, spotted bass, largemouth bass, and longear sunfish tended to travel relatively long distances downstream and much shorter distances upstream. The distances traveled by the remaining species were more nearly equal, but the average distance traveled upstream was always the longer.

The most striking feature of Table 2 has to do with the complex move-

ments (down one stream and up another). For the five species that undertook this type of movement the distances traveled were strikingly longer than for simple upstream or downstream movements. The time free, however, usually did not differ greatly from the time for the other categories, although it usually was somewhat longer.

Extent of movement.—A serious limitation of a tagging study is that only the point of release and the point of recapture are known. The distance traveled is measured along the shortest water route between these points. This length of stream offers only a minimal estimate of the distance through which the fish ranged; it is possible that the fish actually traveled much further. A fish might, for example, go downstream 40 miles and then back 20 miles before it is caught. This travel would be recorded as a simple downstream movement of 20 miles although it actually would be a complex movement of 60 miles within the same stream. If, after moving downstream, the fish had gone up a tributary 20 miles before capture the record would show a complex movement of 60 miles. If, as is almost certainly true, movements of a complex nature occur within a single stream, the miles of stream over which fish have wandered probably are much greater than the records for simple movements indicate. Records of complex movements probably give the most dependable indication of distances traveled.

Although tagging records probably provide a measure of the movements of a species that must be considered minimal, they are the only source of such information we have. In Table 3 the percentage of the various species

TABLE 3.—*Percentages of fish by species which had moved various distances*

[Asterisks indicate species in which some individuals made complex movements]

Species	Movements of less than							
	1 mile	5 miles	10 miles	25 miles	50 miles	100 miles	200 miles	300 miles
Rock bass*	64.1	84.4	92.6	97.8	98.7	99.6	99.6	100.0
Channel catfish*	37.0	55.4	64.1	85.9	94.0	100.0	....	....
Carp*	51.3	69.6	81.7	89.6	93.0	97.4	98.3	100.0
Smallmouth bass*	63.3	81.7	92.7	97.2	99.1	99.1	100.0	....
Green sunfish	77.8	91.1	95.6	100.0	....	....	....	....
Flathead catfish	48.9	72.1	76.7	90.7	100.0	....	....	....
Longear sunfish	70.0	86.7	90.0	96.7	100.0	....	....	....
Largemouth bass	48.0	76.0	84.0	92.0	100.0	....	....	....
Spotted bass	91.7	91.7	95.8	100.0	....	....	....	....
Golden redhorse*	47.4	68.4	68.4	78.9	84.2	94.7	100.0	....
Black redhorse	60.0	73.3	80.0	93.3	93.3	100.0	....	....
Freshwater drum	36.4	45.5	54.5	54.5	72.7	90.9	100.0	....
White crappie	30.0	30.0	40.0	70.0	100.0	....	....	....
Yellow bullhead	80.0	90.0	100.0	....	....	....	....	....

which had moved various distances are shown. Since the complex movements may give a better approximation of the extent of movement than do the apparently simple upstream and downstream movements, the distances traveled by fishes for which complex movements were recorded may be the most accurate. The mobile yellow bullhead, green sunfish, spotted bass, longear sunfish, flathead catfish, and largemouth bass had the most re-

stricted movements. Only a few exceeded 25 miles. Mobile carp and rock bass moved most extensively (over 200 miles) although there is some doubt concerning this record for the rock bass.[1]

Effect of Various Factors on Movement

Locality of release.—The fish tagged in this study were released at 30 sampling stations located on 11 of the major stream systems of Missouri. On most of the streams there were at least three stations, the distance apart depending upon the length of stream within the state. Twelve stations were located near the headwater of a main stream or important tributary. If the location of the release point with reference to the rest of the stream system had any effect upon fish movement, such effects might be most easily determined from the releases at these headwater stations. The possibility for upstream movement from these stations was limited but the chance for downstream movement was great. Therefore, it seemed that fish released at headwater stations would tend more to move downstream than would those released further downstream.

A comparison of the number of returns from species released at headwater stations that made various types of movements or none at all (Table 4) with corresponding data for all recaptures (Table 1) sheds some light on the habitat preferences of the various species. This comparison may be of value in interpreting data on movement. None of the freshwater drum and white crappie and only small numbers of the flathead catfish, spotted bass, carp, and channel catfish recaptured had been released at upper stations. This fact indicates a preference for larger waters. Those species with a large number of releases at headwater stations, notably the two redhorses and the green sunfish, show a preference for headwater conditions. The situation is complicated by the fact that the streams differed greatly in their physical characteristics, from the swift, clear Ozark streams to the sluggish, turbid prairie rivers. Some species were seldom or never taken at certain stations. However, the conclusions as to habitat preference are in general true.

Of the species listed as predominantly sedentary (Table 1), all except the longear sunfish showed an equal or greater tendency to be sedentary when released in headwaters (Table 4). Among those classified as semi-mobile, the carp and largemouth bass released in headwaters showed a tendency toward greater mobility whereas the flathead catfish and the two redhorses tended to be more sedentary. The channel catfish, the only mobile species represented in the headwater releases, tended to be more mobile. It is concluded that, in general, when fish are released in headwater areas: (1) sedentary species tend to be more sedentary and semi-

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1 Two rock bass made complex movements. One traveled downstream and up a tributary for a total distance of 1 mile in 202 days. The other traveled down the Black River 161 miles and up the Current River 126 miles in 230 days. This record met all tests for authenticity so it was included. However, the amount of travel involved differs so much from the pattern established by the other 230 records that there is doubt concerning it.

mobile species which are in their preferred habitat also tend to be more sedentary; (2) mobile species and semi-mobile species not in their preferred habitat tend to be more mobile.

The data on longear sunfish, largemouth bass, and flathead catfish are at variance with these conclusions. The flathead catfish may be disregarded since only one individual was recaptured. The other two species were also represented by such small numbers that their classification as to mobility or habitat preference may have been faulty.

TABLE 4.—*Number of returns from species released at headwater stations and the percentages that made no movement and various types of movements*

Species	Total number	Percentage making no movement	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Rock bass	93	68.8	9.7	19.4	2.2
Channel catfish	32	18.8	15.6	46.9	18.8
Carp	14	42.9	28.6	21.4	7.1
Smallmouth bass	35	74.3	11.4	14.3	....
Green sunfish	28	92.9	3.6	3.6	....
Flathead catfish	1	100.0	....	....	....
Longear sunfish	10	50.0	....	50.0	....
Largemouth bass	14	35.7	35.7	28.6	....
Spotted bass	2	100.0	....	....	....
Golden redhorse	12	66.7	16.6	16.6	....
Black redhorse	12	66.7	8.3	25.0	....
Freshwater drum	0	....	....	....	....
White crappie	0	....	....	....	....
Yellow bullhead	4	100.0	....	....	....

As had been anticipated, most of the mobile fishes tended to move downstream. This tendency was especially marked in the channel catfish. Only the carp, green sunfish, and golden redhorse tended to move in about equal numbers in either direction (if the complex movements are included with downstream movements, as was done earlier).

Variations of movement patterns from stream to stream.—Enough records were available for four species to permit comparisons of the movement patterns in different streams and in some streams at different stations (Table 5). Only those stations and streams which provided a sample of reasonable size are included in the table.

Smaller proportions of the rock bass population were sedentery in the Black, Gasconade, Meramec, and White Rivers than in all streams combined (Table 1), or in the other streams. The percentages of sedentary individuals were high at upper (headwater) stations. At the Upper Meramec the proportion of sedentary individuals was high (71 percent) although the average for the entire stream was low (55 percent).

In the Black, Meramec, and White Rivers more of the mobile rock bass tended to move downstream than up. The results from the Black and Meramec are strongly influenced by the data from their upper stations where most of the records originated. The rock bass from the Upper Piney

and Current No. 5 stations also showed marked downstream movement. At Current No. 5 the cold waters of Big Spring, which enter the river a few miles above the station, may deter upstream movement of rock bass. In the Gasconade River the amount of movement in the two directions was equal as had been true for all streams combined. In the Current, Niangua, and Piney, upstream movement predominated but largely because of a preponderance of data from downstream stations where more of the rock bass were mobile and the tendency was to move upstream.

We may conclude then that (1) in the headwaters rock bass are relatively more sedentary than are those farther downstream, (2) the mobile rock bass from the headwaters tend to move downstream, (3) those from the downstream areas tend to move upstream.

The distribution of fishing intensity has effect upon fish-movement data (Table 5). The Middle Niangua and Upper Current stations were located at state parks, and the Upper Piney station was at a church campground which serves the local community as a park. Fishing is intense in these areas. The proportions of sedentary rock bass were accordingly higher at these stations than at any of the other localities listed in the table. Undoubtedly the returns from sedentary fish and the intensity of the fishery at the release point are related.

For the channel catfish the proportions of sedentary fish were higher than the general average in the St. Francis, Salt, and Gasconade Rivers. In the Osage and Grand Rivers the proportions of sedentary fish were much lower. The results from the Salt and Gasconade are influenced by the records from the lower stations where the numbers of sedentary fish were unusually large. On the other hand, the results from the Osage and Grand Rivers are influenced by the returns from the upper stations where most of the channel catfish were mobile. The tendency toward downstream movement of the mobile channel catfish was strong at the headwater stations. The Grand and Osage Rivers are prairie streams with headwaters subject to wide fluctuations in volume of flow. In late summer and fall, habitat suitable for channel catfish may become very limited. This condition probably accounts for the tendency toward downstream movement and also for the high degree of mobility of the channel catfish in these areas. Since the headwaters of the Grand and Osage are typical of prairie streams in Missouri, it seems that the amount and direction of movement of their channel catfish population also may be considered typical of such streams. A large proportion of the mobile fish from the headwaters stations made complex movements. This behavior is to be expected since the farther upstream fish are released, the greater are the opportunities to make such movements.

The proportions of sedentary channel catfish varied widely at lower stations; at the extremes were the Salt River (90 percent) and Grand River (25 percent). No explanation can be given for this variability. The general statement that a larger number of the channel catfish were seden-

TABLE 5.—*Total number of returns of important species by watersheds and stations with percentages of fish making no movement and various types of movements*

Species, watershed and station	Total Number	Percentage making no movement	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Rock bass					
Black					
Upper	31	45.2	19.4	32.3	3.2
Total	33	48.5	18.2	30.3	3.0
Current					
Lower	12	58.3	41.7	....	....
No. 5	12	58.3	8.3	33.3	....
Middle	11	63.6	27.3	9.1	....
Upper	19	78.9	10.5	5.3	5.3
Total	54	66.7	20.4	11.1	1.9
Gasconade	12	50.0	25.0	25.0	....
Meramec					
Upper	14	71.4	7.1	21.4	....
Total	20	55.0	15.0	30.0	....
Niangua					
Middle	32	81.3	9.4	9.4	....
Total	41	78.0	12.2	9.8	....
Piney					
Middle	22	50.0	40.9	9.1	....
Upper	22	90.9	....	9.1	....
Total	51	68.6	23.5	7.8	....
White	16	56.2	6.3	37.5	....
Channel catfish					
Gasconade					
Lower	17	47.1	41.2	11.8	....
Grand					
Lower	24	25.0	45.8	20.8	8.3
Middle	48	41.7	27.1	18.8	12.5
Upper	11	9.1	9.1	54.5	27.3
Total	83	32.5	30.1	24.1	13.3
Osage					
Sac	15	26.7	60.0	13.3	....
Upper	12	16.7	8.3	50.0	25.0
Total	33	24.2	39.4	24.2	12.1
Salt					
Lower	10	90.0	10.0	....	....
Middle	9	22.2	55.5	22.2	....
Total	23	47.8	30.4	21.7	....
St. Francis	12	58.3	41.7	....	....
Carp					
Grand					
Lower	26	50.0	19.2	23.1	7.7
Middle	12	75.0	16.7	....	8.3
Total	43	51.2	20.9	20.9	7.0
Osage	10	36.4	18.2	18.2	27.3

Species, watershed and station	Total Number	Percentage making no movement	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Salt					
Lower	14	64.3	14.3	7.1	14.3
Middle	19	36.8	47.4	15.8	....
Total	33	48.5	33.3	12.1	6.1
St. Francis	15	86.7	13.3	....	....
Smallmouth bass					
Black	10	80.0	10.0	10.0	....
Current	17	64.7	23.5	11.8	....
Gasconade	11	81.8	....	18.2	....
Meramec	14	64.3	7.1	28.6	....
Niangua	16	62.5	12.5	25.0	....
Piney	20	70.0	10.0	20.0	....
White	18	33.3	55.6	5.6	5.6

tary at downstream stations than elsewhere is true for most of the streams. Most of the mobile catfish at downstream stations moved upstream.

Conclusions regarding movements of channel catfish are: (1) channel catfish from headwaters are markedly less sedentary than those farther downstream and (2) most of the mobile channel catfish from the headwaters move downstream but those from downstream areas move up stream.

Carp records were less numerous than those for rock bass and channel catfish and the movement patterns were less clear. Variations between streams in the relative numbers of sedentary fish were wide (Osage, 36.4 percent, to St. Francis, 86.7 percent). However, the results from the Grand and Salt Rivers, the two streams that yielded the most returns, were both near the general average. Variations in the number of sedentary fish from different stations on individual streams also were wide and to a degree inconsistent. The direction of movement by the mobile fish at different stations also varied greatly. It seems probable that, unlike rock bass and channel catfish, the carp has no generally consistent pattern of movement but responds directly to local variations in the habitat. This view is in keeping with the carp's reputation for adaptability.

The physical characteristics of the habitat at individual stations may explain some of the records for carp. At the middle station the Grand River is of moderate size, and for a prairie stream, of relatively stable flow. Numerous deep holes furnish excellent carp habitat. The stream seldom, if ever, overflows in this area. A relatively large part of the carp population might well be sedentary in such a habitat. At the lower station the Grand River is much larger, swollen by waters from numerous tributaries. Deep holes are few, and the broad valley floor is frequently flooded. The scarcity of deep holes, the frequent floods, and the carp's habit of invading overflow waters, would contribute to a high percentage of mobility in the carp population at this station.

At the Lower Salt River station the size of the stream and other physical

conditions are similar to those at the Middle Grand River. The patterns of movement of the carp at the two stations were also somewhat similar. The results from the Middle Salt River are not readily explainable. The stream at this station is rather small, but deep water is abundant, and flooding seldom occurs. A rather high proportion of sedentary carp would be expected. Perhaps a much-frequented fishing spot at a highway bridge a few miles upstream from the area may explain the preponderance of mobile fish that had moved upstream.

Carp, more than other species studied, may have adapted their movements to the physical conditions of the local habitat. Probably they are mostly sedentary in a suitable stable habitat but may be predominantly mobile in a habitat subject to flooding or unsuitable in other respects.

Records of smallmouth bass were scanty. No analysis of differences in behavior from station to station was possible. With a few exceptions, however, the results from the various streams were remarkably consistent. Sedentary fish predominated in all streams except the White River. Perhaps the large proportion of mobile smallmouth bass in the White (66.7 percent) was the result of a subspecific difference in the fish, the type of stream, or the geographical location, but a definite explanation cannot be offered.

Downstream movement of mobile smallmouth bass was much greater than upstream movement in the Gasconade, Meramec, Piney, and Niangua Rivers. Upstream movement was the greater in the White and Current Rivers, while in the Black River movement was the same in both directions. The percentage of tagged fish that moved downstream was higher in the Meramec, Niangua, Piney, and Gasconade Rivers than in other streams. It would seem that the streams fall into two groups with respect to the movement of the smallmouth bass. Several explanations are possible.

The Black, Current, and White Rivers all flow southward and all are in the Arkansas River drainage system which empties into the Mississippi in southeastern Arkansas. The smallmouth bass of these streams are known to be either *Micropterus dolemieui velox* or intergrades between this subspecies and the *M. d. dolemieui* which inhabits the northward-flowing streams of the Missouri Ozarks. If movement is determined by the genetic nature of the fish, the subspecific difference may account for the differences in the movements of the smallmouth bass in the southward-flowing streams.

The entire lengths of the Gasconade, Meramec, Piney, and Niangua Rivers are within Missouri. Only a portion of the upper reaches of the Black, Current, and White Rivers are within the state. The Black River enters the Mississippi lowland and ceases to provide habitat suitable for smallmouth bass before it leaves the state. The entire smallmouth-producing portion of the stream is represented and the amount of movement in either direction was equal. The portions of the Current and White Rivers in Missouri can be termed broadly as headwaters. We might then conclude that in the headwaters the smallmouth bass exhibits a tendency to move upstream rather than down. This explanation is refuted by the fact that the Piney and Niangua rivers are tributaries of other streams and in the

sense in which the term is used in this paragraph could be considered "headwater" streams for their entire length. Yet the movement in these rivers was predominantly downstream.

It is possible also that in the southward-flowing streams, tagged fish which traveled downstream moved out of the state, out of the range of our publicity, and so were not reported when caught. If so, the difference in the movement may be only an apparent one due to inadequate sampling. We have no way of knowing which one or combination of the above possibilities provides the true explanation.

Seasonality of movement.—It is commonly believed that warm-water stream fishes move most in the spring. They are reputed to travel very little in the summer but to start moving again in the fall. These hypotheses were tested for the four most abundant species by tabulating the records by the month of release for all fish free 90 days or less. The 90-day interval was selected because it seemed unlikely that two "periods of movement" would be included in this length of time and yet there would be enough returns each month to give dependable information. The results (Table 6)

TABLE 6.—*Total number of returns of important species free 90 days or less by month of release and percentage making no movement and various types of movements*

Species and month	Total number	Percentage making no movement	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Rock bass					
April	44	75.0	15.9	9.1	....
May	37	56.8	13.5	29.7	....
June	19	68.4	5.3	26.3	....
July	18	72.2	16.7	11.1	....
August	5	100.0	....	....	....
September	1	100.0	....	....	....
October	1	100.0	....	....	....
Channel catfish					
May	10	10.0	40.0	40.0	10.0
June	51	45.1	39.2	9.8	5.9
July	7	100.0	....	....	....
August	3	66.7	....	33.3	....
September	0	....	....	....	....
October	1	100.0	....	....	....
Carp					
April	2	50.0	50.0	....	....
May	10	50.0	20.0	20.0	10.0
June	6	33.3	66.7	....	....
July	13	61.5	23.1	15.4	....
August	7	57.1	....	42.9	....
September	3	33.3	66.7	....	....
October	3	66.7	....	33.3	....
Smallmouth bass					
April	10	80.0	....	20.0	....
May	18	61.0	5.6	33.3	....
June	11	63.6	36.4	....	....
July	9	77.8	....	22.2	....
August	11	72.7	27.3	....	....
September	1	100.0	....	....	....

demonstrate that smaller proportions of all four species were sedentary in the spring than in other months. All species showed high proportions of sedentary fish in the summer.

The data in Table 6 do not show the extent of mobility in the fall although high mobility of carp in September is suggested. Owing to a decrease in fishing intensity after August the number of reports was insufficient to provide dependable records for the later months. Therefore, combined returns were tabulated for fish released between September 1 and November 30, and caught between September 1 and April 30. These limits were selected on the assumption that little or no movement takes place in winter and early spring. The results (Table 7) suggest that channel catfish

TABLE 7.—*Total number of returns of important species from fish released between September 1 and November 30 and caught between September 1 and April 30 and percentages making no movement and various types of movements*

Species	Total number	Percentage making no movement	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Rock bass	10	70.0	....	20.0	10.0
Channel catfish	7	14.3	57.1	14.3	14.3
Carp	11	63.6	18.2	18.2	....
Smallmouth bass	1	100.0	....	....	....

are unusually mobile in the fall but that rock bass and carp are more sedentary than in the spring and summer. The results for carp are contrary to those in Table 6; it is impossible to judge which is more dependable.

Effect of size on movement patterns.—If fish of different sizes exhibit marked differences in their movement patterns, knowledge of this fact would be of great practical value to fishery management. To investigate this problem, the recaptures of the four important species which had been free 365 days or less were tabulated by their length at the time of release. Length groups were based on average lengths at the end of various years of life found in age and growth rate studies made by Missouri Conservation Commission biologists. The rock bass and smallmouth bass values were developed in state wide studies of these species carried on by Patriarche [1] and Lowry,[2] respectively. Average lengths for carp and channel catfish were obtained from Purkett's [3] study of the age and growth of the

1 Patriarche, Mercer H.
Growth of the rock bass in Missouri streams. Mo. Cons. Comm., unpublished data.

2 Lowry, Edward MacLean
The growth of the smallmouth bass (*Micropterus dolomieu* Lacepede) in certain Ozark streams of Missouri. Doctoral dissertation, Graduate School, Univ. of Mo., 1953, 316 pp. (typewritten).

3 Purkett, Charles A.
A study of growth rate of the important stream fishes of the Salt River watershed. Mo. Cons. Comm., D-J Project F-1-R-2, Work Plan 2, Job 5, 1953 Job Completion Report, 47 pp. (typewritten).

fishes of the Salt River watershed. It is not to be assumed that all fish in a certain length group were the same age. However, it seemed desirable to make the length range in the groups correspond to the average annual increment of growth. The results are shown in Table 8.

TABLE 8.—*Total numbers of important species free 365 days or less by length at time of release with percentage making no movement and various types of movements*

Species and Length range (inches)	Total number	Percentage making no movement	Percentage moving upstream	Percentage moving downstream	Percentage making complex movements
Rock bass					
4.5 – 6.2	23	65.2	17.4	13.0	4.3
6.3 – 7.5	74	66.2	16.2	16.2	1.4
7.6 – 8.2	50	64.0	20.0	16.0	....
8.3 – 8.6	17	64.7	11.8	23.5	....
8.7 – 9.0	12	50.0	25.0	25.0	....
9.1 – 9.5	9	44.4	11.1	44.4	....
9.6 – 9.9*	10	90.0	....	10.0	....
10.0*–10.9*	6	100.0	....	....	....
11.0*–12.0*	3	100.0	....	....	....
Channel catfish					
8.5 –10.2	6	66.7	16.7	....	16.7
10.3 –12.1	7	42.9	28.6	....	28.6
12.2 –13.9	26	34.6	23.1	30.8	11.5
14.0 –15.6	28	35.7	46.4	10.7	7.1
15.7 –17.9	41	46.3	39.0	7.3	7.3
18.0 –20.9*	24	33.3	41.7	20.8	4.2
21.0*–22.9*	7	42.9	42.9	14.3	....
23.0*–24.9*	3	66.7	....	33.3	....
Carp					
8.4 –13.0	23	52.2	30.4	4.3	13.0
13.1 –16.1	17	58.9	23.5	17.6	....
16.2 –18.1	13	53.8	30.8	15.4	....
18.2 –19.8	11	45.5	18.2	18.2	18.2
19.9 –21.5	10	50.0	20.0	30.0	....
21.6 –24.0	4	50.0	50.0	....	....
Smallmouth bass					
5.2 –8.4	19	73.7	26.3	....	....
8.5 –10.9	27	59.3	22.2	18.5	....
11.0 –13.0	22	45.5	22.7	31.8	....
13.1 –14.8	10	80.0	10.0	10.0	....
14.9 –15.7	6	66.7	16.7	....	16.7
15.8 –16.1	1	100.0	....	....	....
16.2 –16.3	2	100.0	....	....	....
16.4 –16.5*	..	....	....	....	....
16.6*–16.9*	2	100.0	....	....	....
17.0*–17.9*	2	100.0	....	....	....

*Limits selected arbitrarily.

It is apparent that the smallest groups of rock bass, channel catfish, and smallmouth bass were more sedentary than the average (Table 1). The greatest degree of mobility was exhibited by the intermediate length groups of these three species. Rock bass of 8.7 to 9.5 inches in length showed high numbers of mobile fish. Smallmouth bass up to 13 inches in length were

increasingly mobile but the number of mobile individuals decreased sharply among the larger fish. For the channel catfish the pattern was less consistent. Fish between 12.2 and 15.6 inches and between 18.0 and 20.9 inches in length were more mobile than others, but those between 15.7 and 17.9 inches showed a relatively high proportion of sedentary individuals. Perhaps the limitations of this method of assigning length groups accounts for this inconsistency. The largest channel catfish were sedentary to about the same degree as the smallest fish, but the largest rock bass and smallmouth moved little, if any.

The carp data do not fit the pattern for the other species described above. No very striking differences in the degree of mobility are apparent between any of the length groups although fish of 18.2-19.8 inches in length were most mobile. The small number of records available for the carp limits the dependability of these results. However, if carp of all sizes tend to move in response to physical changes in the habitat, we would expect the results of any analysis which ignores habitat differences to show a remarkable consistent movement pattern.

Concept of a Sedentary and a Mobile Group

The most significant result of this study is the concept that the native population of a stream fish species is made up of two segments, a sedentary group and a mobile group. This concept explains contradictory results which have confused some investigators. It does not refute the findings concerning home ranges advanced by Gerking and Larimore. Rather, it seems to supplement their work if we assume that they investigated only a part of the population (i.e. the sedentary group). Since their procedures were much more detailed and precise, their findings concerning the sedentary group are much more dependable than are ours. In their studies only those fish which remained in a stream section a few hundred feet in length were considered to have made no movement while in the present study this limit was one mile. What is here referred to as the "sedentary group" therefore probably included a number of mobile individuals by their standards.

The concept of a sedentary and a mobile group within the population provides a more logical explanation of many observed phenomena than do other ideas which have been advanced in this field. For example, if the extreme degree of stability reported by Gerking applied to all seasons and under all conditions, repopulation of stream sections from which fish had been extirpated would occur very slowly. The inconsistencies of the theory of random movements proposed by Thompson when compared with these results have already been discussed. Perhaps the movements of the mobile segment of the populations are random but a better method of proof than the "migration constants" is needed. The improbability of a general continuous movement of native fish in one direction, either upstream or downstream, hardly needs comment.

That the tendency toward stability or mobility has a genetic basis is

attested to by the fact that the various species differ greatly in this respect. To argue whether or not individuals within a species move or remain in one locality because of their hereditary make-up or because of the suitability of the environment is fruitless because proof is lacking. Evidence is presented, however, which demonstrates that environmental factors do influence the amount and direction of movement. The release location, the preferred habitat of the species, the stability of the habitat, and the size of the fish all caused changes in the proportion of the population which remained sedentary. The different species were affected to different degrees by these factors.

In the absence of definite migratory behavior, population pressure would seem to be the most probable cause of the movement of native warm-water stream fishes. Young fish at first probably remained near the place where they were hatched. As they grow and their food requirements increase, they range farther and farther. Eventually competition from other fish (either the same species or those with similar habits) forces the individual either to defend a suitable territory vigorously enough to maintain it, or to move on in search of less crowded conditions. The competition might be for food, suitable hiding places, or other necessities. Changes in the habitat caused by floods or droughts might have a similar effect. It seems probable that whether the fish moves or stays is largely a result of heredity. Certainly some species move more often than others. Therefore, the heredity of the individual may govern its behavior in this respect. If the individual moves, it was demonstrated that environmental factors have a bearing on whether the movement will be upstream or downstream. The larger individuals move little, possibly because they are best able to defend from invasion a territory suited to their needs. Competition for territories seems to be keenest among fish of intermediate size, therefore they are the greatest wanderers.

Acknowledgments

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THE EFFECT OF GIZZARD SHAD ON THE FISH POPULATION OF A SMALL OKLAHOMA LAKE [1]

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ABSTRACT

Estimates of the standing crop of fish in two small Oklahoma lakes were made by the short-period simultaneous mark-and-recovery method, employing wire traps. The lakes were similar in physical and chemical characteristics, and each contained bluegill, black and white crappie, redear sunfish, largemouth bass, warmouth, black bullhead, and *Gambusia*. The one lake which also contained gizzard shad, carp, and green sunfish was treated with rotenone to check the accuracy of the population estimate. The lake without gizzard shad had an estimated standing crop of 655 pounds per acre, 608 pounds of which was composed of desirable-sized fish. Recovery from the lake treated with rotenone indicated a standing crop of 1,043 pounds per acre but the weight of desirable-sized fish was 142 pounds per acre less than in the lake without shad. The faster growth, plumper condition, and greater average length of fishes in the lake without shad indicated that direct interspecific competition occurs between centrarchids and gizzard shad in small-lake populations.

The failure of an estimated 39 percent of the fish killed to appear following rotenone treatment emphasizes the necessity for employing the mark-and-recovery method in population studies. The catches of the cylindrical, 1-inch-mesh wire traps did not reflect adequately the numbers of gizzard shad, large carp, and largemouth bass. Other types of gear must be devised to determine accurately and efficiently the standing crops of these species.

INTRODUCTION

Recent fishery-management procedures in various southern states include the temporary reduction or complete elimination of gizzard shad (*Dorosoma cepedianum*) from lakes up to 6,000 surface acres in an effort to alter the numerical relationship of predator to prey. It has been assumed that overabundant shad usurp nutrients and living space from the more desirable fishes, and that these detrimental effects outweigh their value as a forage species.

In order to determine the effect of gizzard shad on a typical Oklahoma small-lake centrarchid population, two impoundments which are of similar age and physical and chemical characteristics were studied in the spring of 1955; only one of the lakes had shad. The apparent magnitude of competition or protocooperation between species in each lake is based on population estimates of the standing crop derived by the short-period simultaneous mark-and-recovery of fish in wire traps. Following trapping,

[1] Contribution No. 54 of the Oklahoma Fisheries Research Laboratory, a cooperative unit of the Oklahoma Game and Fish Department and the University of Oklahoma Biological Survey.

the lake containing shad was poisoned with rotenone to check the reliability of the population estimate.

Description of the Lakes

Chickasaw Lake and Ardmore Rod and Gun Lake are located in the foothills of the geologically renowned Arbuckle Mountains of south-central Oklahoma in the drainage of Caddo Creek, a tributary of the Washita River. Both were built for recreational purposes near 1900, and have been stocked periodically with various sunfishes and channel catfish for the past 40 years. Fishing pressure was estimated by each lake caretaker at about 200 fisherman-hours per acre per year during the last decade. The average annual precipitation at nearby Ardmore is 36 inches, the average air temperature is 62° F. (January, 43° F.; July, 84° F.), and the average annual number of frost-free days is 235.

Chickasaw Lake, impounded in 1910, is 3 miles northeast of the city of Ardmore (Twp. 45, Range 2E, Carter County). The area was 28.7 acres during the trapping period. The average depth was 6 feet and the maximum was 18 feet. Heavy stands of cattail and bulrush exist in water less than 2 feet deep around the entire shoreline and stonewort (*Chara* spp.) occurs in the shallower water. Lotus plants blanketed about 2 acres of the surface prior to eradication in the summer of 1955. The mud bottom has an irregular contour due to the presence of a submerged rocky ridge along the longitudinal axis of the lake. The drainage area comprises about 400 acres of hilly black-jack-post oak forestland. The water has an overage pH of 8.2 (7.8—8.4), a methyl-orange alkalinity of 140 p.p.m. and a Secchi-disc transparency of 24 (16—36) inches. The turbidity is due largely to plankton.

Ardmore Rod and Gun Lake, impounded in 1896, is 2 miles north of Ardmore adjacent to U.S. Highway 77 (Twp. 45, Range 2E, Carter County). At the time of study it had a surface area of 16.3 acres, an average depth of 6.7 feet, and a maximum depth of 19 feet. Cattails and bulrush are present in shallow water along the south shore and at the head of the lake, but are cut periodically and are not as abundant as at Chickasaw Lake. Sparse patches of *Chara* occurred prior to the application of rotenone in June 1955. The mud bottom is bowl-shaped and relatively smooth. The drainage area is 100 acres of rolling tall-grass prairie which is mowed annually. The average pH of the lake water is 8.2 (7.6—8.4), methyl-orange alkalinity is 160 p.p.m., and transparency is 20 inches (16—30). Turbidity is due largely to plankton.

Chickasaw Lake was 12.4 acres larger than Rod and Gun Lake at the time of the study and its capacity was 170 acre-feet, compared to 110 acre-feet for the latter. Both lakes have similar shoreline and submerged vegetation, transparency, pH, and alkalinity. A mild, unstable thermocline exists in each from 10 feet to the bottom during the summer. Both have large populations of slider and musk turtles, snails, and aquatic insects, and rank among the most fertile bodies of water in the state.

Stocking of both lakes has been haphazard. For example, 9,300 fingerling largemouth bass, 3,400 crappie (spp.), 5,200 redear sunfish, 2,700 bluegill, 600 green sunfish, and 8,000 channel catfish have been placed in Chickasaw Lake in the past 10 years, and a similar procedure has been followed at Rod and Gun Lake. In 1955, both lakes contained: bluegill, *Lepomis macrochirus;* white crappie, *Pomoxis annularis;* black crappie, *Pomoxis nigromaculatus;* redear sunfish, *Lepomis microlophus;* largemouth bass, *Micropterus salmoides;* warmouth, *Chaenobryttus coronarius;* black bullhead, *Ictalurus melas,* and mosquitofish, *Gambusia affinis.* Gizzard shad, carp *Cyprinus carpio,* and green sunfish, *Lepomis cyanellus,* also were present in Rod and Gun Lake.

Methods

In estimating the populations of the lakes, the fish were captured in cylindrical traps, 6 feet long and 3 feet in diameter. The framework of ⅜-inch reinforcing rod, was covered with 1-inch-mesh chicken wire; a 5-inch funnel opened at each end. The unbaited traps were marked with a wooden float attached with sash cord. Trapped fish were measureed individually, marked by clipping the right pectoral fin near the base, and returned to the water from a canvas holding tub. Fish were released at random points within 50 to 200 yards of the site of capture. The traps were moved about and placed to obtain the highest catch.

Twelve traps were set in Chickasaw Lake on April 6, and lifted each day until May 14. A total of 400 trap-lifts captured 3,766 fish, representing seven species. On April 23, 10 traps were put in Rod and Gun Lake and lifted each day until May 14. In 200 trap-lifts, 3,039 fish were captured, representing nine species.

Population estimates were made by the method of maximum likelihood (Schnabel, 1938) wherein the estimated population is equal to the summation of the fish captured on any one day, multiplied by the number of marked fish present on that date, divided by the summation of recaptures. The conditions which must hold if this equation is to yield valid results (Ricker, 1948) were considered to be fulfilled in both lakes. No losses were evident in handling and marking, and fish injured in the traps were not returned to the water. Fin regeneration during the 2-month period was slight; marks could be detected easily by asymmetry and shortness of the fin. Random mixing of marked and unmarked fish was accomplished by constantly shifting the traps and by scattered releases. Angling effort during April and May was limited, and records were kept of fish removed by fishermen. The total catch in Rod and Gun Lake in 132 fisherman-hours during May included 452 sunfish, 130 crappie, and 9 largemouth bass. The catch was slightly lower at Chickasaw Lake. Examination of the daily length-frequency distribution of trapped fish in each lake indicated that some growth did occur from April 6 to May 14, but that recruitment was negligible.

Length measurements were taken from all marked fish (Table 1) in

order to construct estimated length-frequency distribution of each species (Figs. 1-5). Weights were recorded in grams from a representative sample of each species, and length-weight formulae derived (Table 2) from which the estimated standing crop in pounds was computed. Lower effective length limits of the traps are: sunfishes, 4.2 inches; crappies, 4.4 inches; largemouth bass, 5.5 inches.

TABLE 1.—*Number of length measurements of fish from Ardmore Rod and Gun Lake and Chickasaw Lake*

[These measurements were the basis for the length-frequency distributions in Figures 1-5]

Species	Number of fish measured			Percentage of estimated population measured		
	Rod and gun		Chickasaw	Rod and Gun		Chickasaw
	Trapping	Rotenone	Trapping	Trapping	Rotenone	Trapping
Gizzard shad	89	423	....	....	0.9	....
Bluegill	1,756	2,578	1,962	4.1	6.8	4.8
White crappie	532	954	113	11.5	12.2	7.0
Black crappie	283	864	852	6.7	21.5	8.0
Redear sunfish	214	311	381	17.7	26.8	11.7
Largemouth bass	34	288	42	12.6	21.5	30.6
Warmouth	34	55	247	11.8	17.4	14.1
Green sunfish	3	56	....	....	25.0	....
Carp	1	46	....	....	50.0	....
Black bullhead	5	1	13	27.8	6.7	35.1
Total	2,951	5,576	3,610	5.6	5.5	6.3

[1]Less than 0.05

TABLE 2.—*Length-weight equations for various fishes from Rod and Gun Lake and Chickasaw Lake*

[Total length in inches; weight in pounds]

Species	Rod and Gun Lake		Chickasaw Lake	
	Number of fish	Length-weight relation	Number of fish	Length-weight relation
Gizzard shad	243	$\log W = -3.8893+2.6850 \log L$	...	.....
Bluegill	214	$\log W = -4.1049+2.9500 \log L$	109	$\log W = -4.6498+3.2813 \log L$
Redear sunfish	247	$\log W = -4.2015+3.0065 \log L$	73	$\log W = -4.3156+3.1103 \log L$
Largemouth bass	89	$\log W = -2.6979+3.3327 \log L$	29	$\log W = -4.0371+2.8090 \log L$
Black crappie	125	$\log W = -5.0715+3.3701 \log L$	104	$\log W = -4.3030+3.0006 \log L$
White crappie	174	$\log W = -4.6333+3.1145 \log L$	54	$\log W = -4.3857+3.0281 \log L$
Warmouth	16	$\log W = -5.0544+3.4908 \log L$	78	$\log W = -4.4871+3.2089 \log L$

POPULATION ESTIMATES

Chickasaw Lake had an estimated 2,000 fish per surface acre, weighing 655 pounds, on May 14 (Table 3). Bluegill represented 70 percent of the total number and 67 percent of the weight, and crappies 20 percent of the number and weight. The average length of each species except largemouth bass was unusually high, and the rate or growth (Table 4) and condition

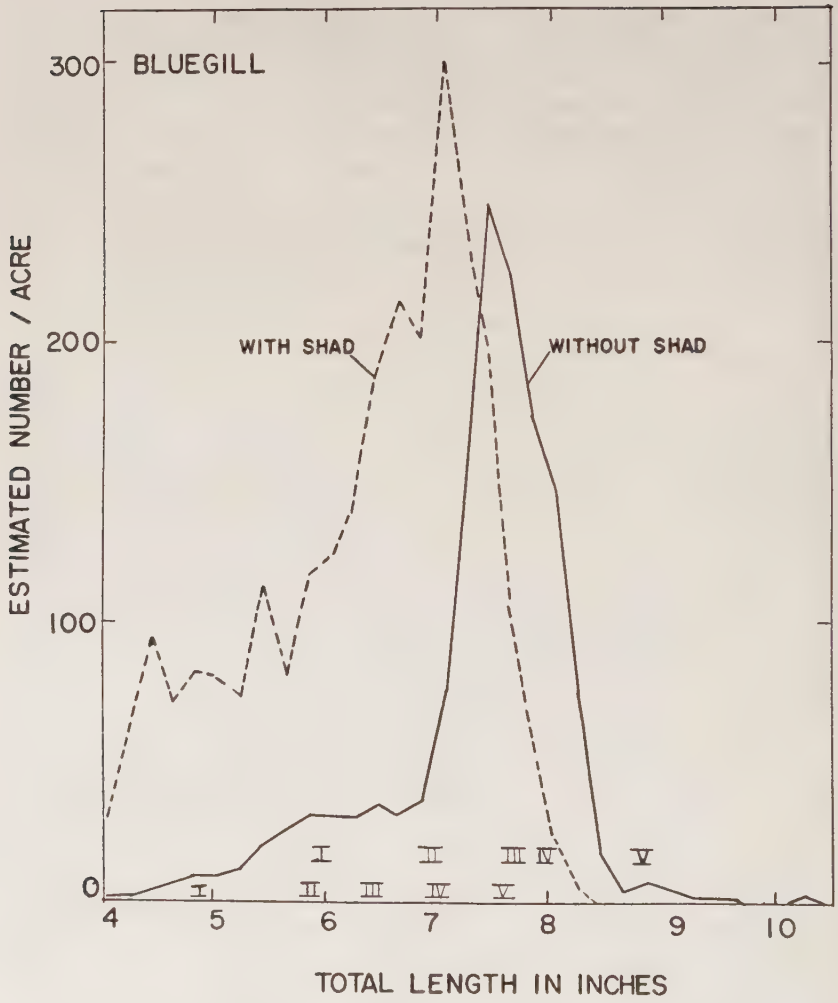

FIGURE 1.—Length frequency of the bluegill in Chickasaw Lake (without shad, solid line) and Rod and Gun Lake (with shad, dotted line), based on fish caught in wire traps, May 14, 1955. Fish are grouped in 0.2-inch length intervals. Roman numerals indicate average lengths of age-groups in Chickasaw Lake (upper row), and in Rod and Gun Lake (lower row).

(Table 5) were above the state average. The bass population was low, and the largest individual taken measured only 11.1 inches.

Rod and Gun Lake contained an estimated 3,261 fish per acre, weighing 533 pounds on May 14 (Tables 6 and 7), but estimates of the gizzard shad and carp populations were not possible. Excluding shad and carp,

TABLE 3.—*Estimated fish population in 28.7-acre Chickasaw Lake*

[Based on mark-and-recovery in wire traps. Confidence limits (95 percent) presented in lower and upper limit columns are based on the assumption of Poisson distribution, wherein the variance is equal to the summation of recaptures]

Species	Number marked	Recaptures	Lower confidence limit	Population estimate	Upper confidence limit	Number per acre	Pounds per acre	Average total length
Bluegill	1,962	47	31,700	40,700	57,000	1,420	437	7.3
Black crappie	852	33	7,000	10,700	23,300	370	122	7.9
White crappie	113	4	800	1,600	8,100	60	17	8.2
Redear sunfish	381	23	2,300	3,300	5,500	110	67	9.0
Largemouth bass	42	3	140	300	.....	10	3	9.1
Warmouth	247	44	630	810	1,140	30	7	6.8
Black bullhead	13	2	13	37	.....	1	2	11.4
Total	3,610	156	42,583	57,447	.....	2,001	655	...
Number per acre	.....	..	1,485	2,001	.....	.....	...	...

TABLE 4.—*Comparison of the calculated growth of various fishes in Rod and Gun South Lake and Chickasaw Lake with the state average of small lakes (5-110 acres)*

[Based on the assumption of a direct proportion body-scale relationship]

Species and lake	Number of fish	Total length (inches) at end of year					
		1	2	3	4	5	6
Bluegill							
Rod and Gun	62	3.7	5.4	6.4	7.0	7.6	....
Chickasaw	109	4.6	6.7	7.4	8.0	8.7	....
State average	..	3.2	5.0	6.1	6.9	7.3	....
Black crappie							
Rod and Gun	55	3.2	6.5	8.2	9.1	....	....
Chickasaw	106	4.5	8.5	9.9	10.7	....	....
State average	..	2.7	6.0	7.8	9.5	....	....
White crappie							
Rod and Gun	62	3.6	7.2	9.3	....	....	....
Chickasaw	58	5.2	8.0	10.3	12.0	....	....
State average	..	2.7	5.7	8.0	10.0	....	....
Redear sunfish							
Rod and Gun	54	4.3	6.6	7.5	8.1	8.5	8.7
Chickasaw	73	5.6	7.6	8.6	9.2	9.7	10.1
State average	..	3.6	5.9	7.2	8.2	9.5	10.7
Largemouth bass							
Rod and Gun	64	5.5	9.0	11.9	14.8	16.4	18.1
Chickasaw	29	6.2	9.6	11.0	....	....	....
State average	..	4.7	8.5	11.2	13.7	16.3	18.0
Warmouth							
Rod and Gun	22	3.1	5.0	6.0	6.5	7.2	....
Chickasaw	81	4.1	6.2	7.0	7.7	....	....
State average	..	3.3	5.1	6.2	6.9	7.9	....
Green sunfish							
Rod and Gun	12	2.6	4.2	5.3	6.1	....	....
Chickasaw	..	....	....	....	....	....	....
State average	..	3.8	5.9	7.2	7.5	....	....
Carp							
Rod and gun	20	15.7	24.1	26.7	....	....	....
Gizzard shad							
Rod and Gun	39	5.1	7.8	9.4	10.3	11.5	12.9

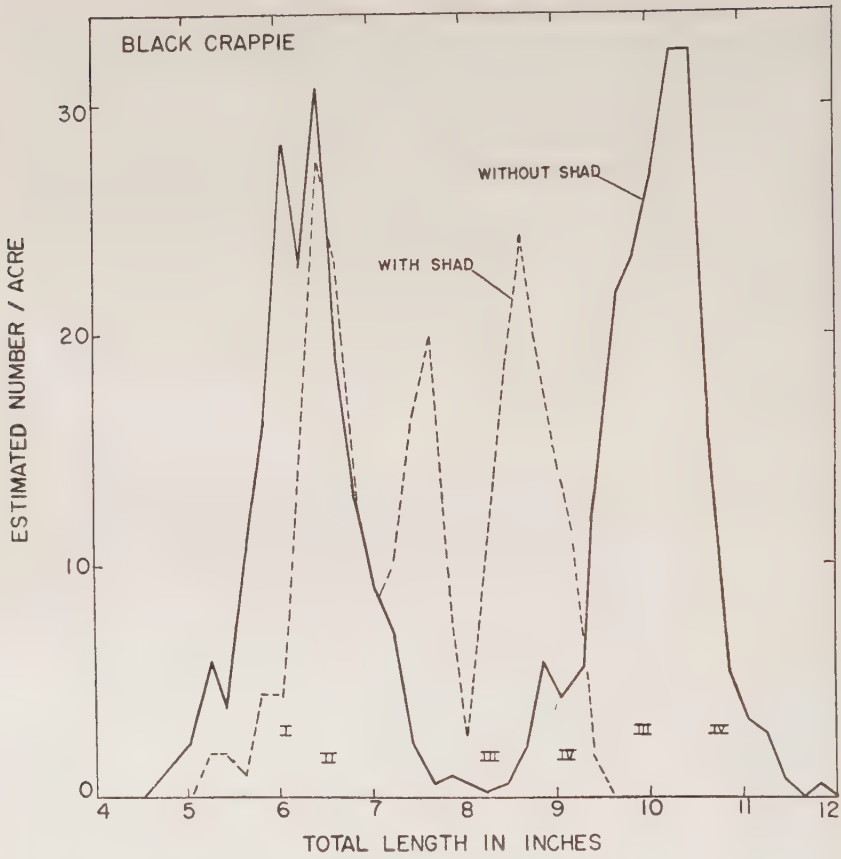

FIGURE 2.—Length frequency of the black crappie in Chickasaw Lake (without shad, solid line) and Rod and Gun Lake (with shad, dotted line), based on fish caught in wire traps, May 14, 1955. Fish are grouped in 0.2-inch length intervals. Roman numerals indicate average length of age-groups in Chickasaw Lake (upper row), and in Rod and Gun Lake (lower row).

bluegill constituted 80 percent of the number and 74 percent of the weight of the total population, and crappies 17 percent of the number and weight. Average lengths were in the desirable-size range with the exception of the crappies, and the rate of growth was above the state average (Table 4). The coefficient of condition, however, was well below the Oklahoma average (Table 5).

A comparison of the populations in the two lakes as estimated from the trapping indicated that the six principal fishes in Chickasaw Lake—the lake without shad—displayed faster growth, plumper condition, and a

TABLE 5.—*Comparison of the coefficient of condition of various fishes in Rod and Gun Lake and Chickasaw Lake with the Oklahoma average*

[The formula for the coefficient is $C = \frac{W10^5}{L^3}$ The values were estimated from length-weight equations; see Table 2 for the equations for Rod and Gun Lake and Chickasaw Lake]

Species and lake	Coefficient of condition at 1-inch intervals							
	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
Bluegill								
Rod and Gun	66	65	64	64	63	..	..	..
Chickasaw	..	67	70	74	77	79	..	..
State average	59	62	64	66	68	70	..	..
Black crappie								
Rod and Gun	33	36	38	41	43	45	..	..
Chickasaw	..	50	50	50	50	50	50	50
State average	39	42	45	48	50	52	54	56
White crappie								
Rod and Gun	36	36	37	38	39	39	..	..
Chickasaw	..	46	46	46	46	47	47	47
State average	38	40	43	45	48	50	52	53
Redear sunfish								
Rod and Gun	64	65	65	65	65	65	65	..
Chickasaw	..	74	76	77	78	79	80	81
State average	56	60	63	65	68	70	72	73
Largemouth bass								
Rod and Gun	..	34	37	38	40	42	43	45
Chickasaw	..	42	42	41	40	39	38	37
State average	39	40	43	45	46	47	49	50
Warmouth								
Rod and Gun	..	60	66	71	76	..	..	..
Chickasaw	..	74	76	78	80	82	..	..
State average	70	74	76	79	81	83	..	..

TABLE 6.—*Estimated fish population in 16.3-acre Ardmore Rod and Gun Lake*

[Based on mark-and-recovery in wire traps and on counts made after poisoning with rotenone. Confidence limits (95 percent) presented in lower and upper limit columns based on the assumption of Poisson distribution, wherein the variance is equal to the summation of recaptures. Numbers in parentheses are estimates that are not based on recovery of marked fish]

Species	Traps — May 14			Rotenone — June 12		
	Lower confidence limit	Estimate	Upper confidence limit	Lower confidence limit	Estimate	Upper confidence limit
Gizzard shad	.....	.....	.....	35,600	48,800	77,500
Bluegill	37,600	42,500	48,900	34,700	37,900	41,800
Black crappie	2,700	4,200	9,600	3,300	4,000	5,100
White crappie	4,200	4,600	5,100	6,600	8,000	9,500
Redear sunfish	1,000	1,200	1,500	1,100	1,400	1,800
Largemouth bass	120	270	.....	800	1,300	5,100
Warmouth	120	290	.....	300	550	2,700
Green sunfish	3	.....	.....	90	(370)	.....
Carp	1	.....	.....	50	(340)	.....
Black bullhead	5	14	.....	5	(14)	.....
Total	45,749	53,074	.....	82,545	102,674	.....
Number per acre	2,810	3,260	.....	5,060	6,300	.....

TABLE 7.—*Estimated fish population in 16.3-acre Ardmore Rod and Gun Lake*

[Based on mark-and-recovery by wire traps and on counts after pooisning with rotenone. Numbers in parentheses denote estimates that are not based on recovery of marked fish]

Species	Trap capture, April 23-May 14					Recovery after poisoning, June 12-14				
	Number marked	Recaptures	Estimated number per acre	Estimated pounds per acre	Average length	Number recovered	Percentage of marked fish recovered	Estimated number per acre	Estimated pounds per acre	Average length
Gizzard shad	89	0	....	...	9.2	15,358	39	3,000	513	8.1
Bluegill	1,756	31	2,610	411	6.4	9,851	26	2,330	366	6.3
Black crappie	283	4	260	53	7.6	1,779	23	250	44	7.3
White crappie	532	33	280	40	7.0	1,195	30	480	42	6.0
Redear sunfish	214	15	70	26	8.3	341	29	90	21	6.7
Largemouth bass	34	2	20	16	10.1	288	21	80	27	9.1
Warmouth	34	2	20	4	6.6	97	18	30	4	4.9
Green sunfish	3	0	....	...	5.7	93	(25)	(20)	(2)	4.8
Carp	1	0	....	...	17.8	46	(50)	(5)	(21)	18.4
Black bullhead	5	1	1	3	16.7	1	...	(1)	(3)	....
Total	2,951	88	3,261	553	....	29,049	26	6,286	1,043	....

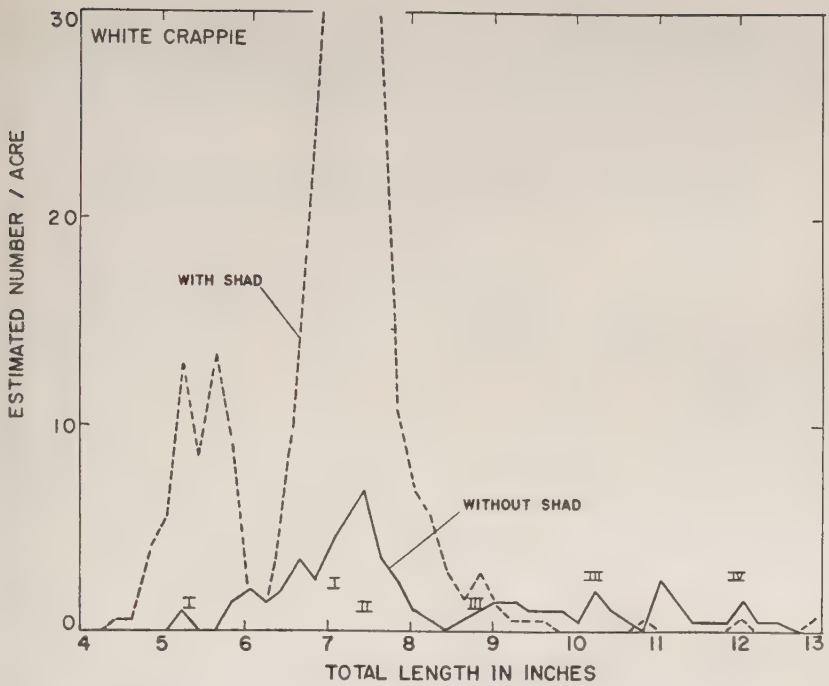

FIGURE 3.—Length frequency of the white crappie in Chickasaw Lake (without shad, solid line) and Rod and Gun Lake (with shad, dotted line), based on fish caught in wire traps, May 14, 1955. Fish are grouped in 0.2-inch length intervals. Roman numerals indicates average lengths of age-groups in Chickasaw Lake (upper row), and in Rod and Gun Lake (lower row).

greater average length than did the same species in Rod anad Gun Lake—the lake with shad (Tables 3-7, Figs. 1-6). Although there were about 386 more desirable-size individuals per acre in the lake with shad, the total weight was 142 pounds per acre less than in the lake without shad (Table 8). The difference was principally attributable to the greater number and weight of redear sunfish and black crappie in the desirable-size range in the lake without shad.

Yearling black crappie, redear sunfish, and warmouth were not represented in the estimate of Rod and Gun Lake due to gear selectivity, but their numbers were not considered of sufficient magnitude to invalidate the comparison. Rapid growth during the first year and early part of the second year of life (March 15 to May 14) of the remaining species in Rod and Gun Lake, and of all species in Chickasaw Lake, placed them above the lower effective trap limits (Fig. 1–5).

The length-frequency curves of bluegill, redear sunfish, and warmouth in both lakes were skewed to the right (Figs. 1, 4, and 5), and the modes

occurred at greater lengths than are noted in many population studies. This unusual distribution indicates that recruitment by age-groups I and II had been sharply limited, and that the lakes were sampled during a period when the numbers of desirable-size fish were at a maximum.

TABLE 8.—*Estimated number and weight of desirable-size fish per acre*
[Based on length distributions of fish caught in traps, in Ardmore Rod and Gun Lake and Chickasaw Lake on May 14, 1955]

Species[1]	Number per acre		Pounds per acre	
	Rod and Gun	Chickasaw	Rod and Gun	Chickasaw
Bluegill (6)	1,800	1,293	386	424
Black crappie (8)	100	197	30	100
White crappie (8)	27	20	7	11
Redear sunfish (6)	72	107	25	66
Warmouth (6)	15	23	3	6
Green sunfish (6)	4	0	1	0
Largemouth bass (10)	10	2	14	1
Total	2,028	1,642	466	608

[1]The figures in parentheses are the total lengths (inches) above which fish are considered desirable.

Rotenone Treatment of Rod and Gun Lake

In order to check the accuracy of the population estimate, and as an experimental management procedure, Rod and Gun Lake was treated with rotenone on June 12, 30 days after completion of trapping. Three days prior to treatment, hauls were made with a 75-foot, ½-inch-mesh seine, so that fish smaller than those taken in the traps could be added to the number of marked individuals. A total of 101 bluegill 17 shad, 40 redear sunfish, and 13 white crappie which were below the lower effective trap limit on May 14 were fin-clipped and returned to the lake. Traps containing fish were placed at various depths from 6 to 18 feet, to check the speed and extent of penetration of lethal concentrations of rotenone. On the day of poisoning, the temperature was 74° F. at the surface and 70° F. at 18 feet. Ten gallons of emulsifiable rotenone (Chem-Fish) were sprayed on the surface, and two 50-pound bags of 5-percent powdered rotenone were dragged behind boats in an effort to apply a concentration of 1.0 p.p.m. to 80 percent of the water volume. Fish were alive in traps below a depth of 10 feet 10 hours following treatment, but all were dead 24 hours after treatment. Nine men were employed for 2½ days (200 man-hours) to pick up, measure, weigh(and bury fish. Approximately 29,000 fish were checked individually and over 2 tons of additional fish were disposed of by burial The estimated standing crop in pounds per acre on June 12 (Table 7) is based on average weights of fish collected during the 30-hour period immediately following treatment (Table 9).

Quadrat counts of windrowed fishes on the third day indicated that about 5,060 gizzard shad, 20,580 sunfishes (predominately bluegill), 2,030

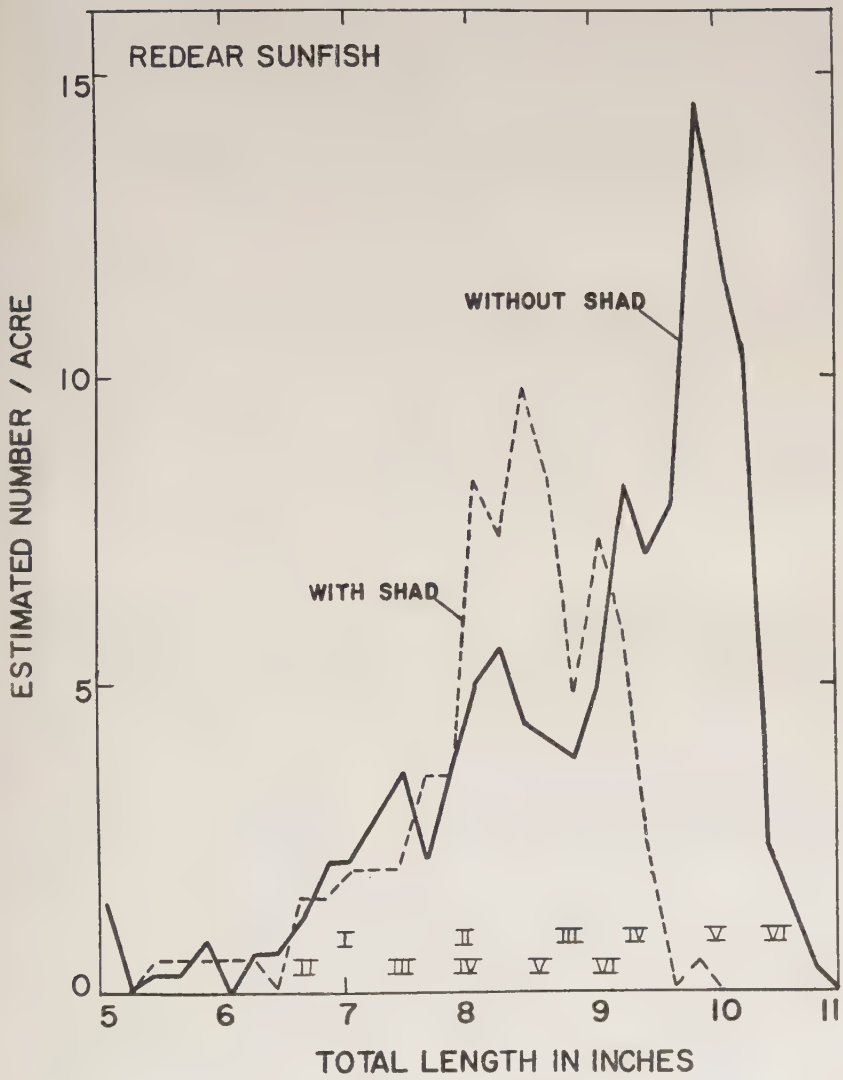

FIGURE 4.—Length frequency of the redear sunfish in Chickasaw Lake (without shad, solid line) and Rod and Gun Lake (with shad, dotted line), based on fish caught in wire traps, May 14, 1955. Fish are grouped in 0.2-inch lengths intervals. Roman numerals indicate average length of age-groups in Chickasaw Lake (upper row); and in Rod and Gun Lake (lower row).

crappies, and 160 largemouth bass (6-11 inches) remained on the shore at the end of the study. A comparison of the numbers recovered (Table 7) plus the windrowed fish, with the population estimate obtained indicates that about 56 percent of the total population (42 percent of the shad, 42 percent of the crappie, 78 percent of the sunfishes, and 33 percent of the largemouth bass) appeared and were available for collection.

Young-of-year bass, crappie (both species), and gizzard shad were not adequately picked up following poisoning. If a 25-percent recovery is

TABLE 9.—*Number of fish weighed following rotenone treatment of Ardmore Rod and Gun Lake on June 12*

[Pounds per acre estimates of the standing crop on that date are based on the computed average weights]

Species	Number weighed	Total weight (pounds)	Average weight (pounds)	Species	Number weighed	Total weight (pounds)	Average weight (pounds)
Gizzard shad...	15,023	2,575.5	0.17	Warmouth...	16	6.4	0.21
Bluegill.....	7,252	1,141.8	0.16	Green sunfish...	56	6.2	0.10
Black crappie...	574	102.5	0.18	Carp.....	46	171.0	3.72
White crappie..	1,141	100.5	0.09	Black bullhead.	1	0.2	....
Redear sunfish..	281	88.3	0.31				
Largemouth bass	86	70.4	0.82	Total.....	24,476	4,262.8	....

assumed, the lake contained on June 12 approximately 3,600 young-of-year bass, averaging 1.9 inches, and a similar number of crappie, averaging 1.6 inches. The numbers of young shad were not believed to exceed 5,000, averaging 1.8 inches. Adults of the other species were ripe, but none of the female bluegill, redear sunfish, or warmouth examined were spent, and no young were recovered.

Trapping was resumed 1 week after the rotenone treatment. The catch per unit effort during a 12-day period indicated that about 5 percent of the total population, (6 percent of the bluegill, 4 percent of the black crappie, 24 percent of the white crappie, and 60 percent of the warmouth), had survived. Seine hauls 3 months later revealed that green sunfish and black bullhead also escaped eradication. Gizzard shad, redear sunfish, largemouth bass, and carp apparently were completely eliminated.

The segment of the population which was killed but not recovered amounted to 39 percent of the estimated total, or about 40,000 individuals. Predation by turtles was observed, and probably accounted for a substantial portion of the unrecovered fish. The turtle population was very high, for as many as 34 individuals were caught in a single trap following rotenone treatment. Various authors (Miller, 1950; Moorman and Ruhr, 1951) have stated that the recovery of marked fish following poisoning is always incomplete (22 to 65 percent), and that total poundage figures based on recovery alone are correspondingly inaccurate. Results of the pick-up at Rod and Gun Lake are in agreement with their observations, and emphasize the need for employing the mark-and-recovery method in establishing accurate estimates of standing crop.

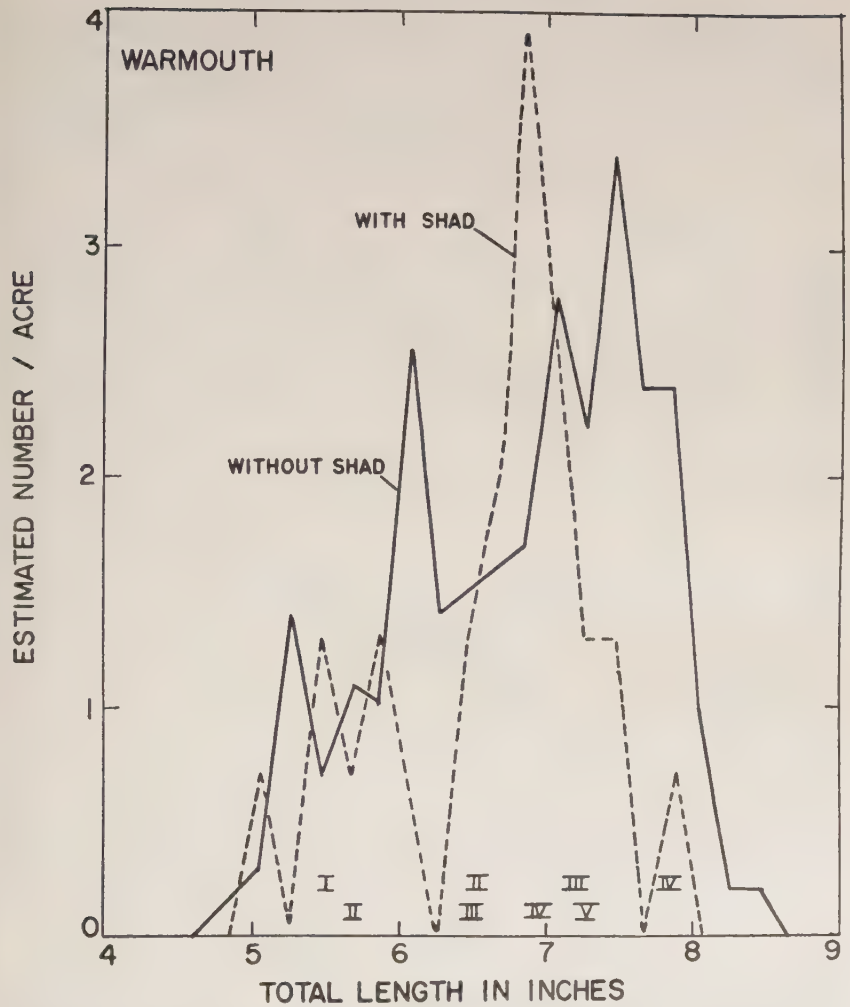

FIGURE 5.—Length frequency of the warmouth in Chickasaw Lake (without shad, solid line) and Rod and Gun Lake (with shad, dotted line), based on fish caught in wire traps, May 14, 1955. Fish are grouped in 0.2-inch length intervals. Roman numerals indicate average lengths of age-groups in Chickasaw Lake (upper row); and in Rod and Gun Lake (lower row).

COMPARISON ESTIMATES FROM TRAPPING AND POISONING

Estimates of the numbers of bluegill, black crappie, and redear sunfish in Rod and Gun Lake based on trap capture and on rotenone recovery were remarkably similar (Table 7). The differences between the two esti-

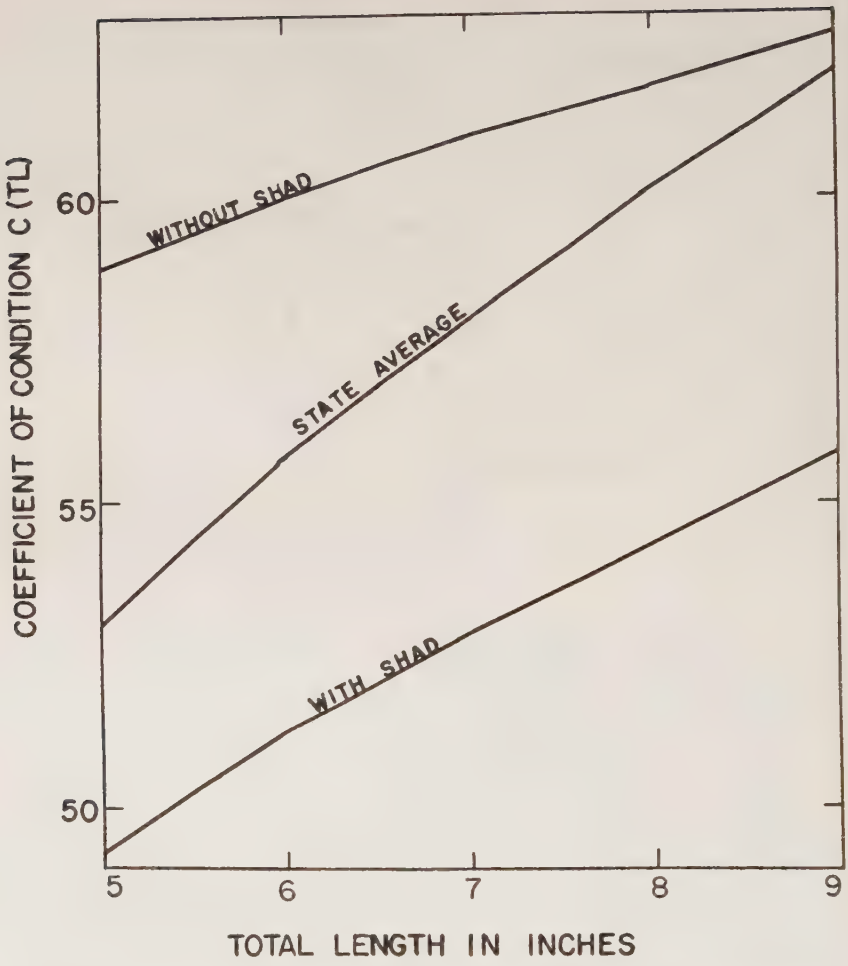

FIGURE 6.—Average coefficient of condition (see Table 5) of six fishes (bluegill, black crappie, white crappie, redear sunfish, warmouth, and largemouth bass) in Chickasaw Lake (without shad) and Rod and Gun Lake (with shad), compared with the state average.

mates for white crappie and warmouth are attributable to recruitment by yearling fish. Experience at Rod and Gun Lake and similar bodies of water in Oklahoma indicates that the traps now in use are incapable of adequately sampling gizzard shad and carp (over 12 inches) and that for some unknown reason estimates for largemouth bass based on trap capture are typically 3 to 5 times lower than the actual population. Addition of the estimates for gizzard shad (513 pounds per acre) and carp (21 pounds

per acre) doubled the total poundage based on trap recovery. Other differences in estimate of the standing crop are caused primarily by a decrease in the average length of each species due to recruitment and mortality, and by weight losses occurring after death (Krumholz, 1950) which influenced the average weight of the poisoned fish.

Management Implications

The final standing-crop estimate of 1,043 pounds per acre in Rod and Gun Lake (Table 7) is above any previously recorded from this physiographic region, and is principally attributable to the presence of gizzard shad. Species other than shad totaled 530 pounds per acre. Four nearby ponds (0.3–4.0 surface acres) with a similar species composition but without shad had estimated crops of 330 to 495 pounds per acre. The centrarchid population of 655 pounds per acre in Chickasaw Lake exceeds that for Rod and Gun Lake by 125 pounds. It is believed that this difference is due to the presence of gizzard shad in the latter body of water. Chickasaw Lake fishes, with the exception of largemouth bass also, had greater average and maximum lengths.

In an analysis of published estimates of standing crops, Carlander (1955) cited an average of 28.6 pounds of largemouth bass per acre in 13 midwest reservoirs without gizzard shad, and 18.9 pounds of bass per acre in 9 reservoirs with shad. Evidence from 21 lakes included in his paper indicated that standing crops of bluegill were not affected by gizzard shad. Largemouth bass in Rod and Gun Lake appeared to benefit from the presence of shad as, according to the data from the trap fishing, they outnumbered Chickasaw Lake bass by 2 to 1, and the standing crop in pounds was 5 times greater (Tables 3 and 7). Recovery after poisoning increased the estimate for bass from 16 to 27 pounds per acre in Rod and Gun Lake and it is probable that the Chickasaw Lake trap estimate was low in the same proportion. The production of large bass was greater in the lake with shad, but the difference was not large enough to warrant recommending the stocking of shad as a forage fish.

On the basis of pond experiments Swingle (1949) concluded: "Combinations of bluegills-shad-bass did not appear promising because large shad accumulated in the ponds and reduced the size of the adult bluegills." It is believed that gizzard shad had a depressing effect upon the growth and condition of sunfishes and crappies in Rod and Gun Lake, but that they promoted the existence of larger numbers of these fishes (Figures 1–5). Fast growth rendered shad unavailable as forage after the first summer of life, and the large number of 2- to 6-year-olds evidently competed directly with the other species for food materials. Some degree of protocooperation between shad and white crappie was indicated by the large population of the latter species in Rod and Gun Lake in comparison with Chickasaw Lake (Fig. 3). The presence of green sunfish in Rod and Gun Lake and their absence in Chickasaw may also be linked with the environment-altering effects of gizzard shad.

Redear sunfish grew faster, were in better condition and lived longer than any of the other sunfishes in both lakes (Tables 4 and 5). Inasmuch as they were less numerous than bluegill it appears that redear would be the more suitable sunfish to stock in combination with largemouth bass in lakes of this type. Black crappie produced more catchable-size individuals (Fig. 2), and were in better condition in both lakes than white crappie (Table 5), and should provide the better fishing in small lakes with proper habitat conditions. Bluegill dominated the centrarchid population of both lakes, but were not serving adequately as a forage fish for largemouth bass in either lake. Practical methods of controlling their numbers have not been devised; a search for a more satisfactory forage species is now in progress in Oklahoma.

The wire traps yield satisfactory estimates of populations of sunfish, crappie, and bullhead in lakes under 50 acres if fished at the rate of about one trap per acre for 15 lift-days when the water temperature is above 55° F. They do not adequately sample populations of gizzard shad, carp, or largemouth bass; seining or hoop-netting must be employed in conjunction with wire traps in lakes which contain these species.

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THE TROUT FISHERY OF THE TAILWATER BELOW DALE HOLLOW RESERVOIR [1]

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ABSTRACT

The 7.3 miles of tailwater below Dale Hollow Dam were initially stocked with rainbow trout (*Salmo gairdneri*) in 1950. In 1953, creel records indicated that a minimum of 16 percent of the 16,500 fingerling-stocked fish were captured by anglers within 12 months after stocking. The rainbow trout creeled averaged 9.4 inches long, and had grown at a monthly rate of 15 millimeters in length and 26 grams in weight. On the basis of growth rates it was decided that an annual stocking of approximately 25,000 fingerling rainbow trout would most benefit the fishery. To maintain suitable water temperatures throughout the tailwater in the summer, a minimum cold-water discharge below the dam was established. Threadfin shad (*Signalosa petenensis*) were stocked in the reservoir in an attempt to establish a supplemental food supply for trout in the tailwater. The stocking of brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), and cutthroat trout (*Salmo clarki*) in the tailwater has been only slightly successful. The Dale Hollow tailwater presently supports 7,000 put-and-take trout-fishing trips per year at a cost to the Tennessee Game and Fish Commission of less than 20 cents per trip.

INTRODUCTION

A reservoir tailwater is usually described as that portion of a stream below a dam that is directly affected by the discharge of water through or over the dam. A tailwater may terminate at its confluence with a larger stream or at the backwaters of another reservoir.

Tennessee has 10 tailwaters that are cold enough to support trout. All of these cold waters are below storage reservoirs, or impoundments used primarily for flood control and hydro-electrical power. The history and general limnological features of the East Tennessee tailwaters have been described by Pfitzer (1954).

Most of the cold tailwaters are large, wide rivers that have a continuous minimum flow of water discharged through the dams. These high minimum water flows for the most part make difficult the study of the trout populations or the relationship between carrying capacity and angling harvest.

In Tennessee tailwaters, trout are not stocked in sufficient numbers to utilize the carrying capacity. Moreover, the trout populations in these tailwaters are not adequately harvested by angling.

1 This study was partly financed and administered through Federal Aid, Dingell-Johnson Act.

2 Formerly with the Tennessee Game and Fish Commission.

The tailwater below Dale Hollow Dam, although not typical of most of Tennessee's cold tailwaters, has stream characteristics and water-flow schedules that provide excellent opportunities to study many of the problems concerning fishery management in tailwaters.

The dam, a concrete structure 178 feet high, was constructed by the U. S. Army, Corps of Engineers, in 1943. The reservoir surface area at elevation 651 feet mean sea level is approximately 30,000 acres and the water depth is 151 feet at spillway level. Annual water-level fluctuation rarely exceeds 25 feet.

The tailwater is 7.3 miles long, drops 2.3 feet per mile, and flows into the Cumberland River in Clay County, Tennessee. The water flow is carried through the dam by three turbines with a combined maximum capacity of 5,900 cubic feet per second. When the turbines are not in operation, there is a natural cold water discharge of 19 cubic feet per second. The amount and periodicity of the water discharge depend primarily upon the demand for power. Shutdown periods of several days are common in the summer and fall. Water discharge schedules may vary from year to year, depending on the amount of water in storage.

Water Temperature and Flow

The water discharged below the dam is always clear, turbidity less than 5 p.p.m., and water temperatures range from 45° to 56° F. The greatest monthly variation is 3° F.

Water levels of the tailwater fluctuate 10 feet, depending upon the amount of water discharged. At the start of a discharge the water level rises to its maximum within a few minutes; return to the minimum after the water is shut off may take several hours.

The volume and frequency of the water discharge are, of course, extremely important to the trout fishery. In past years, during high water temperatures during shut-down periods of several days in summer have been harmful to trout in the lower half of the tailwater. Frequent discharge is important not only to maintain low water temperatures for the trout but also to stabilize temperatures for maximum food production.

In summer, the cool stream basin attracts large numbers of terrestrial animals which are washed into the water by the frequent rapid changes in water levels. Millipedes have been the most important contributor in this type of trout food.

During the water shut-off periods the tailwater consists of a series of long shallow pools with poor trout and stream cover. Few pools reach a depth of 5 feet, and the bottom material consists mostly of flat limestone bedrock and course gravel. The minimum discharge of 19 cubic feet per second has in the past maintained water temperatures suitable for trout in the upper 3 miles of the tailwater during extended shut-off periods.

History of the Fishery

It was not until 1950 that the Dale Hollow tailwater was investigated for the possibility of establishing a trout fishery. Until rainbow trout were stocked, fishing was practically non-existant in the tailwater. Fish samples taken with rotenone in August 1950 indicated fair populations of bluegill (*Lepomis m. machrochirus*), white crappie (*Pomoxis annularis*), largemouth bass (*Micropterus salmoides*), black bullhead (*Ameiurus m. melas*), and gizzard shad (*Dorosoma c. cepedianum*). As far as is known, warm-water fishes do not reproduce successfully in the Dale Hollow tailwater. Walleye (*Stizostedon v. vitreum*), sauger (*Stizostedion canadense*), and smallmouth bass (*Micropterus d. dolomieui*)—all common in the Cumberland River—are seldom found in the Dale Hollow tailwater. Fish samples taken since 1950 have shown a gradual decrease in numbers of warm-water fishes.

From 1950 to 1952, 4,000 fingerling rainbow trout were stocked annually in the Dale Hollow tailwater with excellent results. Within 18 months after the initial stocking 4- and 5-pound rainbow trout were taken by angling. By 1953, the Dale Hollow tailwater was becoming well known for its trout fishery.

In 1953, 5,500 rainbow trout 3 to 4 inches, total length, were stocked in March, and 7,000 and 3,500 fish 4 to 6 inches long were stocked in May and July, respectively. It is with these fish later termed "fingerlings", that the present study is primarily concerned. In addition, 500 10- to 15-inch tagged rainbow trout were stocked.

A study of the trout fishery provided by the rainbow trout stocked in 1953 was initiated in order to determine survival, growth, harvest, optimum size and numbers for stocking, and fishing success. An understanding of these problems in Dale Hollow tailwater would be applicable in management both there and in other tailwater trout fisheries where information is presently lacking and difficult to obtain.

General observations of the trout fishery were made from 1951 through 1955. The present study was conducted primarily from June 1953, to June 1954, inclusive.

Materials and Methods

Fish examined were taken by anglers and electric shocker. The electric shocker was a 240-volt, 6-ampere unit; the electrodes were used about 20 feet apart. During water shut-off periods, the electric shocker captured fish effectively. After capture, the fish were anesthetized with urethan, examined, and returned to the water.

Trout were sampled with the electric shocker near the middle of each month. Water shut-offs that permitted fish sampling with electric shocker

occurred in all months of the 13-month comprehensive study, excepting February, April, and May.

A creel census was conducted on the tailwater each week during water shut-off from June 1953 to June 1954, inclusive. The census-taker checked creels during 154 of the 245 days when no water was discharged and the total fish harvested was adjusted each month according to the "no-flow" days not covered by the census. The census-taker checked fishermen in the upper 3 miles of tailwater only. Not over 60 percent of the fishermen could have been contacted during the census days. No adjustments of data were made to compensate the omission. Moreover, considerable fishing was observed but not recorded during periods of water discharge.

Counts of fisherman below the dam in 1952 and 1953 were conducted by personnel of the U. S. Army, Corps of Engineers. For a period of 12 months, from 6:00 a.m. to 6:00 p.m., counts were made daily at 3-hour intervals of the fishermen utilizing the tailwater who were observable from the dam, a distance of approximately 300 yards.

The 500 creel-sized rainbow trout stocked in July 1953 were tagged at the anterior insert of the dorsal fin with a No. 1 strap tag. The 16,000 fingerling rainbow trout stocked in 1953 were fin clipped differently for each stocking (Table 1).

TABLE 1.—*The 1953 stocking records for the fin-clipped fingerling rainbow trout in Dale Hollow tailwater*

Date of stocking	Number	Fin clipped	Average weight (grams)
March 7	5,500	Right pelvic	9
May 9	3,500	Adipose	18
May 23	3,500	Left pectoral	21
July 25	3,500	Right pectoral	24

The Dale Hollow tailwater was divided into eight zones and all trout examined were identified as to the zone of capture (Fig. 1).

The standard and total lengths of all fishes were measured in millimeters. Fish less than 2 pounds were weighed in grams; weights of fish over 2 pounds were recorded to the nearest 0.1 pound.

The rainbow trout were fin clipped at the hatchery before stocking. Pectoral, pelvic, and adipose fins were clipped with excellent success. During the study, only 9 (0.6 percent) of the 1,405 rainbow trout examined were not identifiable by fin clip markings.

Fishing Conditions, Methods, and Success

The tailwaters in Tennessee are open to trout fishing throughout the year. No size limits are imposed. Most of the trout fishing is done during periods of low water flow or complete shut-down in all tailwaters. Steady high water discharge below most of the storage reservoirs has resulted in

poor fishing conditions and inadequate harvest of the trout populations. Weekend shut-downs below Dale Hollow dam, however, has provided excellent fishing conditions and trout harvest.

Dale Hollow tailwater is readily accessible and during water shut-down periods wading and bank fishing are common throughout. During water discharge, some still fishing is successful near the dam and creek back-

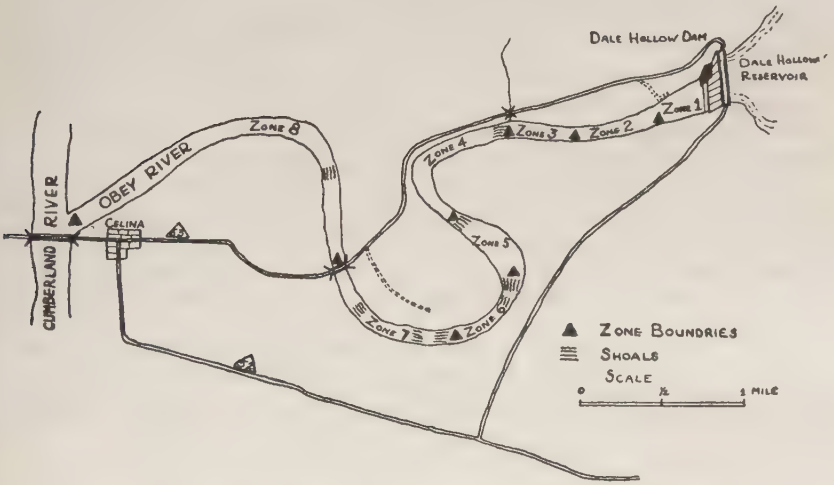

FIGURE 1.—General map of Dale Hollow tailwater and zoned areas.

waters during the late fall and winter. Float fishing by boat during high water has provided a limited amount of trout fishing.

In 1952 and 1953, personnel of the Corps of Engineers made counts (at 3-hour intervals) of all tailwater fishermen that could be observed from the dam. A count of 2,482 fishermen in 12 months indicated that 7 percent of the observed daily fishing was at 6:00 a.m., 20 percent at 9:00 a.m., 27 percent at noon, 24 percent at 3:00 p.m., and 21 percent at 6:00 p.m. The winter (October-March) and the summer counts were similar.

During the study 1,301 fishermen were contacted on the tailwater to determine fishing success and types of gear and bait. Casting rods, spinning rods, and flyrods were used by 73, 18, and 9 percent of the fishermen, respectively. Natural baits were employed by 86 percent. Only 14 percent used artificial lures.

Approximately 69 percent of the "natural-bait" fishermen used worms and 30 percent doughballs. Doughballs were common only when worms were difficult to obtain. Artificial lures consisted of 67 percent spoons (primarily copper colored), 12 percent plugs, and 21 percent flies, or spinner-fly combinations. Fishing success was nearly equal for artificial

and natural baits (about 1.8 rainbow trout per trip). The average number of fishermen per party was 2.1 and the average fishing trip lasted 3.3 hours. Twenty-eight percent of the fishermen were not Tennessee residents.

Harvest of Rainbow Trout

A total of 16,000 fin-clipped, 3- to 6-inch rainbow trout averaging 4.6 inches long and weighing 595 pounds were stocked in the Dale Hollow tailwater from March through July 1953. By June 1954, anglers had removed at least 2,616 or 16 percent of these fish. The average total length was 9.4 inches. The weight of these fish was 760 pounds or 128 percent of the weight of all fish stocked. The average individual gain was from 16 grams at planting to 132 grams at recapture. Each pound of rainbow trout stocked in 1953 provided for at least 4.9 fishing trips.

Recovery of the rainbow trout stocked in May and July was high. However, the 3- to 4-inch fish stocked in March disappeared almost entirely by May. Many had been observed in several small warm-water tributaries to the tailwater in April. The highest recovery (27 percent harvest by number and 174 percent by weight) came from the third stocking (3,500 fish) in late May.

None of the stocked fish became important in the harvest before July 1953. The largest number recovered by angling was in October 1953 (Fig. 2); by weight, however, the highest harvest was in February. Increas-

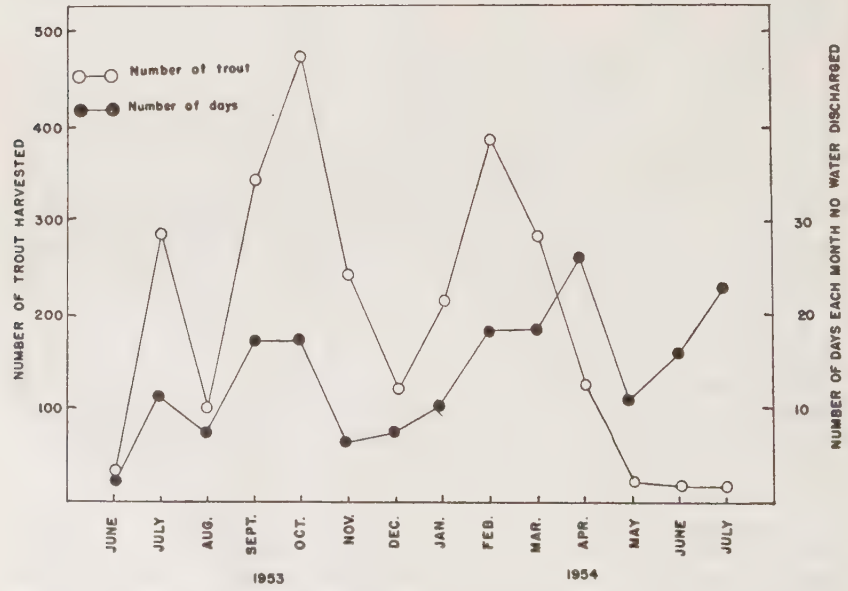

Figure 2.—Anglers' harvest from 16,000 fingerling rainbow trout stocked in 1953, in the Dale Hollow tailwater.

ed water discharge in November, December, and January limited the catch during those months. After April 1954, the rainbow trout stocked as fingerlings in 1953 were relatively unimportant in the creels. The fingerling-stocked rainbow trout supported a sizeable fishery for 9 months, from July 1953 through April 1954. Creel-sized trout were then stocked until July 1954, in order to provide a 12-month fishery.

The predominance of July-stocked fish in the returns of the rainbow trout in 1954 (Fig. 3) gives some indication of the importance of staggering the time of stocking small trout in order to maintain a more stable fishery.

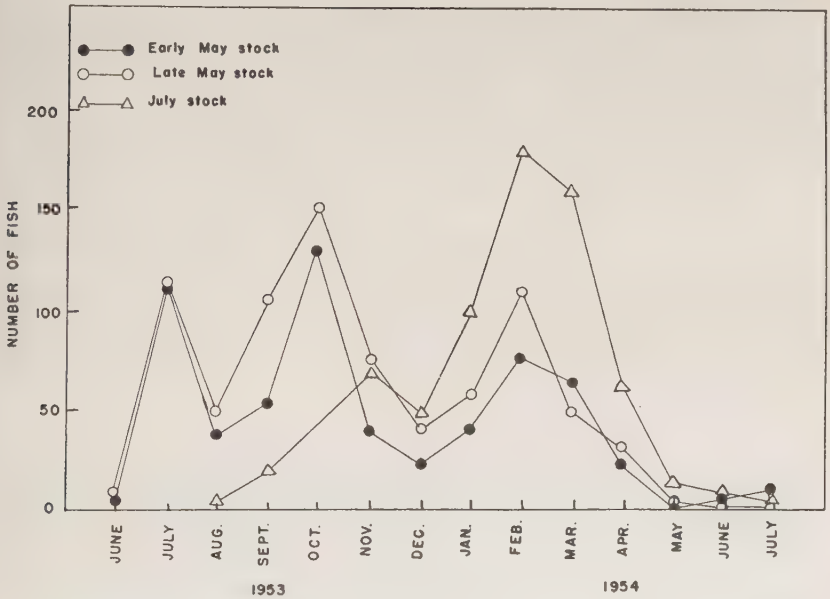

FIGURE 3.—Anglers' harvest from 10,500 fingerling rainbow trout stocked in May and July, 1953, in the Dale Hollow tailwater.

Of the 500 large, tagged trout stocked in the tailwater from May to July 1953, at least 41 percent by number and 49 percent by weight harvested. The incomplete creel census and the type of tag used were not conducive to a high return of the tags. Thirty-three percent of the tagged large fish taken by angling were caught within 30 days. Forty-five, 16, and 5 percent were harvested in the second, third, and fourth months after stocking.

Prior to 1951, little fishing was done in the Dale Hollow tailwater. The fishery resulting from the 1953 stocking of rainbow trout provided more than 3,000 fishing trips in 1953 and 1954. The establishment of the trout

fishery also has resulted in a harvest of warm-water fish that would not have existed otherwise. In 1953, 546 warm-water fish, weighing 214 pounds, were added to the trout creels. These fish were predominately bluegill, white crappie, and black bullhead.

Sexual Maturity and Spawning Success

Rainbow trout stocked in the Dale Hollow tailwater attempted to spawn in October-December. During shut-off periods in these months, redds were common on most shoal areas but during the water discharge the redds were repeatedly destroyed. All redds were constructed in water less than 1 foot deep.

In several areas redds appeared along the gravel banks during high water discharge. When the water was shut off these redds were left stranded. Moreover, dozens of male and female rainbow trout were often stranded in small pot-holes in those areas.

In 1951, heavy fall rains attracted several mature rainbow trout into a small warm-water tributary of the tailwater. In June 1952, several 3- and 4-inch rainbow trout were taken from the tributary. It appeared that these fingerlings were hatched in the stream. Two 7-inch rainbow trout taken from the tailwater by electric shocker in late 1954, were the only other fish that appeared to be progeny of the tailwater stock.

The fingerling rainbow trout stocked in the Dale Hollow tailwater in 1953 were hatched in October 1952. By October 1953 all the male were sexually mature. However, only three of the several hundred female fish examined were mature.

Sex Ratio

The fingerling rainbow trout stocked in 1953 were graded and were representative of the larger half of the hatchery stock of 100,000 fish. The larger fish were planted to lower the number of slow-growing male fish in the fishery.

An examination of 600 of the smaller half of the hatchery stock of rainbow trout in January 1954 showed a sex ratio of 44 percent females whereas 73 percent of 626 "upper-grade" hatchery trout were females. A group of 100 of the largest fish were 92 percent females.

Seventy percent of 895 rainbow trout taken by the electric shocker in the Dale Hollow tailwater and examined for sex were female fish. Eighty-four percent of 245 specimens from anglers' catches were females.

Food and Feeding Habits

The stomach contents of the rainbow trout and the average monthly growth of the fish indicated that abundant food was available during all months and at any water level or rate of discharge. The frequency of different food items in the rainbow trout stomach varied little from month to month. An exception must be made for small rainbow trout which fed

almost entirely upon chiromonids the first month after they were stocked. The frequency of certain food items in fish under 12 inches long was also different than that of the larger fish (Table 2). Algae and associated organisms, and snails were important food for all sizes of rainbow trout. Terrestial insect forms and crayfish were more common in the large than the small rainbow trout, and scuds and mullipedes were more common in the small fish.

Creel-sized rainbow trout began extensive feeding upon algae immediately after they were stocked. Usually small quantities of minute animal forms were found in the algae taken from trout stomachs.

TABLE 2.—*Percentage frequency of food items in rainbow trout stomachs, Dale Hollow tailwater, 1953-54*

Food item	Percentage of stomachs containing food items			Food item	Percentage of stomachs containing food items		
	Fish less than 12 inches (165 stomachs)	Fish 12 inches or longer (63 stomachs)	All		Fish less than 12 inches (165 stomachs)	Fish 12 inches or longer (63 stomachs)	All
Algae (*Chlodophora crispa*)	'59	70	62	Terrestrial insects	30	52	39
Unidentified gastropod	38	46	40	Crustacea			
Chironomidae				Aquatic sow bugs	20	6	16
Larvae	49	8	39	Crayfish	..	11	7
Pupae	36	8	28	Other	9	3	17

The stomach contents of several hundred warm-water fishes taken from the tailwater were examined. Usually the warm-water fish were utilizing the same foods as the trout. Bullhead, white crappie, and bluegill fed extensively on black midge larvae and pupae. Largemouth bass fed frequently on surface insects, and also took some small trout. Snails and some algae were common in most of the stomachs of the warm-water fishes. Crappie often fed on Entomostraca, the only food utilized by warm-water fish that was not part of the rainbow trout diet.

A comparison of the rainbow trout populations in Dale Hollow and Center Hill tailwaters in 1954 and 1955 indicated different growth rates and food habits. Whereas Dale Hollow rainbow trout, stocked as fingerlings, averaged 15 millimeters growth per month, rainbow trout in Center Hill tailwaters averaged 25 millimeters. Investigations proved that the Center Hill tailwater rainbow trout were feeding primarily upon 2- to 3-inch threadfin shad, *Signalosa petenensis,* that were forced through the turbines dead or in a dying condition in September-March. These threadfin shad have supplied an almost inexhaustible food supply. Frequently the water was "white" with the shad.

Dale Hollow reservoir has no threadfin shad and the gizzard shad rarely enter the tailwater through the turbines. Occasionally rainbow trout ap-

peared in the Dale Hollow tailwater that were much larger than average. Several of these fish weighing 4 to 5 pounds, were feeding upon 4- to 6-inch crappie. The crappie apparently had been drawn through the turbines from the reservoir above the dam, and discharged into the tailwater dead or in a dying condition.

Growth in Length

Growing conditions in the Dale Hollow tailwater are uniformly good for rainbow trout during all months of the year. The scales show no annuli. Spawning checks appeared on the scales of some individuals.

The fingerling rainbow trout stocked in 1953 averaged 15 millimeters of growth per month for a 13-month period. At the end of 13 months, the fish averaged 12.6 inches long. The greatest growth was 40 millimeters in the first month. After the rapid growth in the first 2 months, the monthly growth was relatively uniform averaging 12 millimeters.

The data on length of rainbow trout were obtained from 821 fish recovered by angling and 1,405 taken by electric shocker. The monthly average lengths (Fig. 4) indicate that the rainbow trout caught by anglers were usually larger than those taken by electric shocker. The mortality from angling and lack of recruitment are largely responsible for the change in trends of length comparison after December.

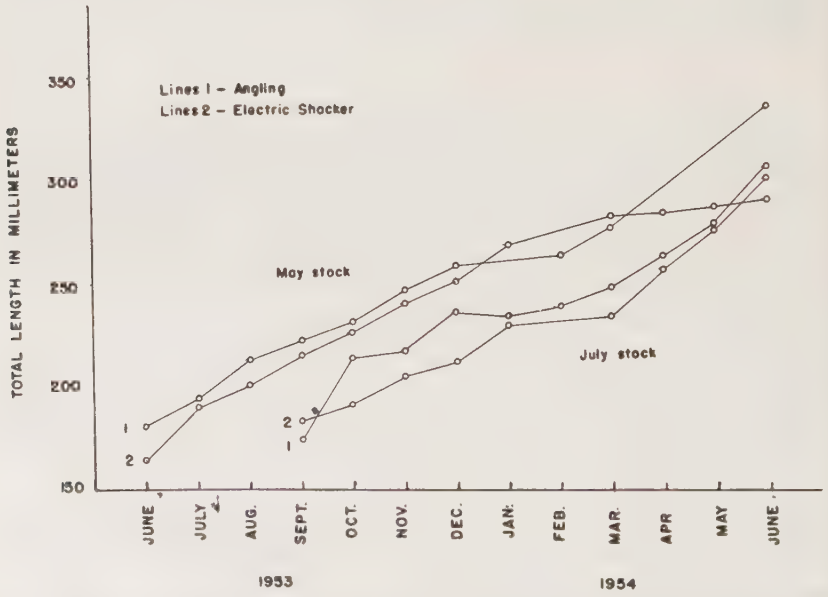

Figure 4.—Monthly average total lengths of the May and July-stocked fingerling rainbow trout compared by method of capture, Dale Hollow tailwater.

The average total length of the male and female rainbow trout for October were 220 and 228 millimeters (8.6 and 8.9 inches), respectively, and for February 255 and 282 millimeters (10.0 and 11.0 inches). During October only 8 millimeters (0.3 inch) separated the average length of the sexes, but by February the females averaged 27 millimeters (1.1 inches) larger than the males. The average monthly growth rates for the male and female fish for the spawning period, October-December, were 9 and 16 millimeters (0.4 and 0.6 inch), respectively.

The monthly average total lengths of rainbow trout stocked as fingerlings in 1952-1954 indicated similar growth each year irrespective of the number of fish stocked (Table 3). Growth decreased, however, in 1955

TABLE 3.—*Comparison of total lengths (inches) of rainbow trout recovered from Dale Hollow tailwater at various intervals after planting as fingerlings*

[Number of fish in parentheses]

Year of stocking	Number stocked	Month after stocking								
		1	2	3	4	5	6	7	8	16
1951.....	4,000	...	...	...	8.4	8.7	9.6	....	....	....
		...	...	...	(7)	(7)	(15)	....	....	....
1952.....	4,000	...	6.3	8.1	9.6	...	10.0	10.6	....	....
		...	(32)	(49)	(12)	...	(46)	(8)	....	....
1953.....	16,000	6.5	7.5	8.1	8.6	9.1	9.5	10.0	....	....
		(49)	(416)	(89)	(181)	(239)	(154)	(272)	....	....
1954.....	20,000	...	...	...	...	...	9.8	....	11.0	14.5
		...	...	...	...	...	(82)	....	(75)	(42)
1955.....	30,000	...	...	...	...	...	....	9.2	....	....
		...	...	...	...	...	....	(48)	....	....

when 30,000 fingerling rainbow trout were planted. On the basis of numbers stocked and growth in length, it appears that the optimum numbers of rainbow trout to be stocked annually should be between 20,000 and 30,000 fish.

The creel-sized trout stocked in the Dale Hollow tailwater in 1953 grew on the average of 11 millimeters (0.4 inch) per month for the first 4 months. The average growth rates of these fish were computed from the data for 82 recaptured tagged fish. The monthly increases for the first 4 months were 8, 12, 16, and 5 millimeters (0.3, 0.5, 0.6, 0.2 inch).

GROWTH IN WEIGHT; CONDITION

The average monthly weight increase of the rainbow trout stocked as fingerlings in 1953 was 26 grams (0.9 ounces) during the next 13 months. The growth was 29 grams the first month, decreased to only 10 grams in the fifth month and reached a peak of 56 grams during the twelfth month

(Table 4). The length growth of the rainbow trout varied little after 3 months. However, a great increase in weight occurred after the tenth month. To obtain an optimum harvest in terms of weight, the rainbow trout should not be caught before 10 months.

Eighty-two large, tagged trout recaptured within 5 months after stocking showed an average monthly increase of 30 grams. All 37 tagged trout recaptured within 30 days after stocking had increased in weight.

The average coefficient of condition *K* of 2,195 rainbow trout taken over a period of 13 months was 1.76. In comparison with other rainbow trout populations, this average is relatively high (Carlander, 1950). The limit-

TABLE 4.—*Average monthly length, weight, and growth increment of the fingerling rainbow trout stocked in Dale Hollow tailwater in 1953*

Month after planting	Total length		Length increment (millimeters)	Weight		Weight increment (grams)	Number of fish
	Inches	Millimeters		Ounces	Grams		
0	4.9	125	..	0.6	19	..	...
1	6.5	166	41	1.8	48	29	149
2	7.5	191	25	2.5	69	21	536
3	8.1	205	14	3.4	95	26	204
4	8.6	219	14	3.9	108	13	166
5	9.1	232	13	4.2	118	10	363
6	9.5	245	13	5.0	141	23	125
7	10.0	255	10	5.8	161	20	301
8	10.4	265	10	6.1	172	11	146
9	10.9	276	11	6.6	188	16	105
10	11.2	285	9	7.4	211	23	63
11	11.8	301	16	9.1	257	46	50
12	12.3	312	11	11.1	313	56	12
13	12.6	320	8	12.6	258	45	6

ed monthly variation of the average coefficient of condition indicated uniform growing conditions in the Dale Hollow tailwater. Studies in Pigeon River, Michigan, disclosed a positive correlation between rising water temperatures and the condition of brook trout (Benson, 1953). The nearly constant monthly coefficient of Dale Hollow tailwater rainbow trout demonstrates the effect of uniform water temperatures and food supply upon growth.

The average monthly coefficients of condition of the rainbow trout taken by electric shocker were considerably higher than those of fish taken by angling (Table 5). Length measurements of these same fish indicated that angling selected fast-growing fish which had coefficients of condition lower than average. This finding is contrary to observations on the Pigeon River trout in Michigan (Cooper, 1953a, b). Although Cooper (1953b) suggested that a systematic bias would occur by sampling a population that was being selectively cropped by fishermen, coefficients of condition of rainbow trout taken by electric shocker and angler from Dale Hollow tailwater remained substantially different from month to month. Since more than 50 percent of the total angling harvest of the fish stocked in 1953 occurred in

TABLE 5.—*Average monthly coefficient of condition,* K, *by method of capture for 1,800 yearling rainbow trout from Dale Hollow tailwaters, 1953*

[Standard deviations in parentheses]

Month	Method of capture		Month	Method of capture	
	Electric shocker	Angling		Electric shocker	Angling
June	1.86 (.07)	1.78 (.10)	October	1.80 (.14)	1.71 (.24)
July	1.71 (.10)	1.66 (.26)	November	1.78 (.17)	1.74 (.17)
August	....	1.73 (.20)	December	1.78 (.10)	1.69 (.20)
September	1.84 (.06)	1.73 (.22)			

1953, a systematic bias would have been expected to be amply demonstrated (Table 5).

In the comparison of the coefficients of condition of all rainbow trout collected over a period of 13 months by 1-inch groups, those fish taken by electric shocker had higher coefficients than those taken by angling except for the 9-inch group (Table 6). The smaller rainbow trout tended to have higher coefficients than the larger fish.

TABLE 6.—*The average coefficient of condition,* K, *by inch groups and method of capture of the Dale Hollow tailwater rainbow trout*

[Based upon measurements of 2,032 fish from June 1953 to June 1954. Number of fish examined given in parentheses]

Length (inches)	Method of capture		Length (inches)	Method of capture	
	Electric shocker	Angling		Electric shocker	Angling
6	1.86 (109)	....	10	1.73 (196)	1.68 (157)
7	1.81 (238)	1.70 (73)	11	1.73 (71)	1.65 (76)
8	1.79 (366)	1.75 (213)	12	1.82 (18)	1.64 (21)
9	1.74 (281)	1.76 (205)	13	....	1.73 (1)

The average coefficient of condition of the 275 mature male and 634 immature female rainbow trout captured from October to March by electric shocker were 1.85 and 1.77, respectively. The condition of the male fish

TABLE 7.—*Average monthly coefficients of condition, K, of 909 male and female rainbow trout from the Dale Hollow tailwater, 1953-1954*

[Standard deviations in parentheses]

Month	Sex		Month	Sex	
	Male	Female		Male	Female
October	1.88 (.17)	1.78 (.22)	January	1.79	1.76 ....
November	1.82 (.17)	1.73 (.20)	February	1.87	1.81 ....
December	1.81 (.14)	1.77 (.10)			

decreased from 1.88 in October to 1.79 in January (Table 7). During November, December, and January, the males were attempting to carry out spawning activities. The female rainbow trout had monthly average coefficients of condition that varied only slightly. The coefficients of condition of the fingerling stocked rainbow trout for the same months during different years show considerable variation (Table 8).

MOVEMENT AND MIGRATION

The Dale Hollow tailwater (Obey River) empties into the Cumberland River 80 miles downstream from the Cumberland Lake Dam in Kentucky. The cold water discharge below Lake Cumberland has changed the upper Cumberland River into a relatively cold-water stream. Stocking of rainbow trout in the Cumberland River to date has not been too successful, however.

Six tagged rainbow trout that were stocked in the Dale Hollow tailwater were caught below the locks of the Cumberland River 80 to 90 miles downstream from Dale Hollow Dam. All of these fish were caught in the spring and summer.

TABLE 8.—*Average coefficient of condition, K, of 1,830 yearling rainbow trout taken from the Dale Hollow tailwater, 1951-1954*

[Number of fish in parentheses]

Month	1951	1952	1953	1954	Month	1951	1952	1953	1954
June	....	....	1.82 (149)	....	October	1.80 (7)	....	1.76 (239)	1.88 (82)
July	....	1.90 (32)	1.69 (416)	....	November	1.73 (15)	1.87 (46)	1.76 (154)	....
August	....	1.89 (49)	1.75 (89)	....	December	....	2.01 (8)	1.74 (272)	1.78 (75)
September	1.87 (4)	1.95 (12)	1.77 (181)	....					

In 1952 several 2-pound rainbow trout that had apparently migrated from the Dale Hollow tailwaters were caught below the dam in Center Hill tailwater. No rainbow trout had been seen previously in the Center Hill tailwater and none had been stocked there. The Dale Hollow tailwater was the only source of rainbow trout that could have migrated to Center Hill tailwater. Center Hill tailwater is 25 miles long and flows into the Cumberland River approximately 60 miles downstream from the Dale Hollow tailwater. These fish traveled at least 90 miles. A brown trout, tagged and stocked in the Dale Hollow tailwater in October 1952, was taken by angling 5 miles below the Center Hill dam in the spring of 1953.

Previous to 1954, all trout stocked in the Dale Hollow tailwater were planted within 2 miles of the dam. Within a few weeks these fish usually spread throughout the tailwater in relatively the same numbers in various areas each year. Rainbow trout were often taken by angling in Cumberland River at its confluence with the Dale Hollow tailwater.

In May and June 1954, 10,000 fin-clipped fingerling rainbow trout were stocked at the confluence of the tailwater with the Cumberland River. Electric-shocker samples in the fall of 1954 indicated that few of these fish migrated upstream into the tailwater. Several dozen have been found in the lower tailwater, and three at the dam; otherwise there are no other records of these fish.

The recovery of tagged rainbow trout by electric shocker indicated that many of the creel-sized stocked fish moved freely throughout the tailwater, particularly during the spawning season. Several tagged fish, however, were taken at the same location over a period of 6 to 36 months.

The monthly average lengths of the rainbow trout stocked as fingerlings, indicated that these smaller fish, after dispersal following planting, generally remained in the same area or zone. Unweighted means of the monthly average lengths for each zone (Table 9) increased progressively

TABLE 9.—*Average total lengths of the fingerling-stocked rainbow trout examined from each zone in the Dale Hollow tailwater from September 1953 to May 1954*

Zone number	Number of fish	Length		Zone number	Number of fish	Length	
		Inches	Millimeters			Inches	Millimeters
1	122	9.8	250	5	153	9.2	235
2	99	9.6	245	6	217	9.6	245
3	166	9.4	240	7	93	10.2	260
4	473	9.2	235				

from Zone 5 to Zone 7 and from Zone 4 to Zone 1. A similar trend is demonstrated by Figure 5 which is based on fingerlings stocked in July.

The percentage of trout recovered by angling from each zone gives further indication as to the natural dispersal of the rainbow trout in the tailwater (Table 10). All rainbow trout were stocked at two major points, between Zones 1 and 2, and between Zones 3 and 4. Stocked creel-size trout were harvested mostly from the largest pools.

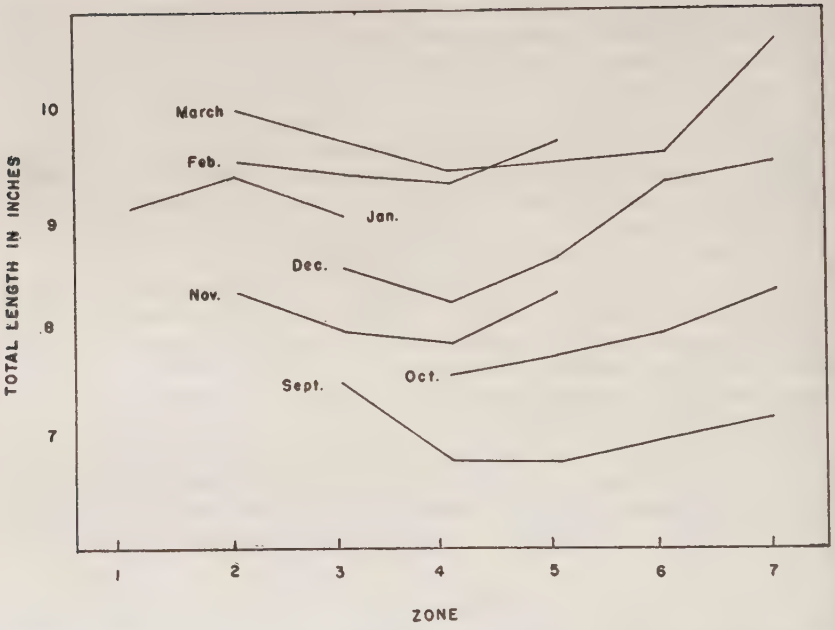

FIGURE 5.—Average monthly total lengths of 535 rainbow trout captured from different physical zones of the Dale Hollow tailwater in 1953–1954.

TABLE 10.—*Percentage distribution among the zone of recoveries by anglers from plantings of fingerling and creel-sized rainbow trout in Dale Hollow tailwater*

Zone	Fingerling	Creel-sized	Zone	Fingerling	Creel-sized
1	20	21	5	5	23
2	12	20	6	7	0
3	25	15	7	1	4
4	28	3	8	1	14

WATER FLOW CONDITIONS

Periods of several weeks when no water was discharged below the dam were frequent in the summers of 1951-1954. During these periods, the waters of Zones 7 and 8 became too warm for trout. With the cooperative efforts of the U. S. Army Engineers, T. V. A., and the Tennessee Game and Fish Commission, a minimum flow schedule was put into effect Below Dale Hollow Dam. In June-October, a minimum water flow of 5 million cubic feet has been established for every 48-hour period. The minimum water flow is provided by operating one turbine for 1 hour once each 48 hours.

This minimum water discharge produced the following results: provided suitable water temperatures in the tailwater for trout during all months

of the year; stabilized water temperatures which allows greater trout food development; and increased the number of terrestrial insects available to the trout by flushing of exposed bank and shoal areas.

Experience with Other Species

Only the rainbow trout fingerlings have successfully provided a fishery in the Dale Hollow tailwater. Four thousand brook trout (*Salvelinus fontinalis*) fingerlings stocked in 1952 disappeared within 6 months. Ten thousand brown trout (*Salmo trutta*) fingerlings stocked in the summer of 1955 showed good growth but poor survival. Four thousand cut-throat trout (*Salmo clarki*) fingerlings have just recently been released in Dale Hollow tailwater with poor results.

No sizeable trout fishery has been established in Tennessee's cold tailwaters by stocking brook or brown trout fingerlings. However, harvest returns of stocked creel-size brown and brook trout has indicated that these fish have relatively high harvestibility if stocked as large fish.

Management

The fact that both fingerling and creel-sized rainbow trout in Dale Hollow tailwater have grown rapidly, survived well, and are satisfactorily harvested by angling has been established. The success of these stockings may be attributed to: uniformly cold and clear water below the dam at all times of the year; maintenance of a year-around trout food supply; lack of size limits on the trout and lack of seasonal restrictions on fishing; accessibility of the tailwater to the fishermen; and the quality of trout stocked.

The fingerling rainbow trout were reared in circular concrete pools and were transported directly from these pools to the tailwater. The trout were not acclimated to the different habitat or feeding conditions before stocking.

Observations in the small warm-water tributaries to Dale Hollow tailwater indicate that certain precautions should be taken when stocking figerling trout in a tailwater that has warm-water tributary streams. If fingerling trout are stocked in a tailwater when these tributary streams have a strong flow of cold water, considerable losses may result from the migration of small trout into these tributaries.

The following fishery management recommendations were made:

1. Approximately 25,000 fingerling rainbow trout should be stocked in the tailwater annually. These fish should be stocked in April, May, June, and July, and should be 3 to 6 inches in total length.

2. A minimum 1,000 creel-size rainbow trout ranging from 10 to 15 inches long should be stocked annually during those months when the number of catchable-size trout is at its lowest, usually during June and July.

3. A minimum water discharge of 5 million cubic feet per 48-hour period

should be maintained each year from June through October.

4. Threadfin shad should be stocked in Dale Hollow Reservoir, not only as a desirable reservoir forage fish, but also as a food for trout in the tailwater.

The recommendation on stocking and minimum water flow were put into effect on January 1, 1955. The threadfin shad stocked in 1955 successfully reproduced that year but are not yet abundant enough to provide the tailwater with trout food. The tailwater in 1955 provided a year-around "put-and-take" rainbow trout fishery that supported approximately 7,000 trout-fishing trips at a cost to the Tennessee Game and Fish Commission at less than 20 cents for each trip.

Acknowledgments

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DEVELOPMENT OF RAINBOW TROUT BROOD STOCK BY SELECTIVE BREEDING

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Abstract

Management programs to maintain and increase the sports fishery require large numbers of strong, healthy, acclimatized fingerlings for restocking the lakes and streams. To produce the fingerling trout needed, stocks of fish are first developed and selected at fishery laboratories, then tested in the field. At the University of Washington over a period of 23 years of intensive selective breeding, rainbow trout (*Salmo gairdnerii*) stocks have shown increased growth rate, earlier maturity, increased tolerance to warm water temperatures, resistance to disease, and greatly increased egg production. The egg production has been most satisfactory, rising from an average of less than 1,000 eggs from 4-year-old spawners in 1932 to an average of 3,894 eggs for 2-year-old females, 5,029 for 3-year-old females, and 4,984 eggs for 4-year-old females in 1955.

Selective breeding of fish has been conducted for almost as long as have experiments with other domestic animals. The earliest experiments in purposeful selective breeding of fish were carried on with carp and goldfish in China and Japan. Smith (1924), in describing the history of the cultivation of goldfish, mentioned that goldfish developed from the wild, olivaceous-colored form were known to the Japanese as early as 1500 A.D.

Goldfish have been modified in a spectacular manner by selective breeding. Not only have the colors been changed from olive-green to gold, black, white, red, blue, purple, lavender, or calico, and the scales reduced so as to be almost transparent, the soft parts modified, and protruding eyes developed, but also the caudal fin has been modified by an actual bilateral separation of the bones that support the tail.

Objective selective breeding of trout is fairly recent; however, the indications are that trout, too, may be modified in many ways if the effort is expended in a planned, orderly fashion. In a series of papers, Wright (1951 and 1952) described the basic genetics of trout breeding and the benefits that may be expected from the inclusion of a plan of selective breeding in a management program.

In the applied field of trout breeding, a number of workers have reported success in attempts to develop stocks of fish to fit their local needs. Hayford and Embody (1930) listed as advantages obtained from 10 years of selection of eastern brook trout (*Salvelinus fontinalis*): increased rate of growth; marked increase in the average number of eggs produced by each female; and resistance to disease.

By selective breeding of rainbow trout at the Hot Creek Hatchery in

California, Lewis (1944) developed a brood stock that spawned in October rather than during the normal spring spawning season. Not only was the spawning season changed; among the selected fish at the Hot Creek Hatchery there was an increase from 53 percent to 98 percent in three generations in the number of fish spawning for the first time at 2 years of age. Egg production for 2-year-old females increased from 723 eggs to an average of 1,693 eggs.

Some of the problems of rapid growth and early maturity from select brood stocks of rainbow trout were discussed by Millenbach (1950). It is pointed out that fish from 2-year-old spawners in the lakes where they have been stocked frequently are near maturity at the time of capture by the sports fishermen. Such mature fish, often dark in color, are not eagerly sought by the fishermen, who prefer slower growing, but bright fish in their creels.

The problems of developing disease-resistant strains of trout were discussed by Wolf (1953). The development of disease-resistant stocks of fish seems very possible, but achievement of positive results may require a number of years.

For the past 23 years, selective breeding of rainbow trout (*Salmo gairdnerii* Richardson) has been carried out at the School of Fisheries, University of Washington. The objective of this project has been to produce large numbers of strong, healthy, acclimatized fingerlings for use in lake and stream management.

At the onset of the program, local races of rainbow trout from wild stock and from hatcheries in the vicinity were obtained and transferred to the ponds at the School of Fisheries, where they were reared to maturity. The fish that survived reached maturity at 4 years of age. The spawners of the 1932 brood-year, with which the selection-breeding experiments were initiated, weighed 1½ pounds at maturity and produced from 800 to 1,200 eggs at their first spawning. The fingerlings produced by these spawners were selected for growth; the largest and strongest were retained for subsequent selection and use as brood stock.

The process of mass selection was continued for the first 10 years. The rate of growth of the fish increased and the age to maturity decreased. Beginning with the 1942 brood-year the methods were changed and selections of the individual fish substituted for mass selection from the entire lot.

The procedure then became one of selecting the brood stock from not only the largest, strongest fish, with the earliest maturity, but also from those which spawned at the desired season of the year and which produced the largest number of eggs with the greatest percentage of hatch. The fingerlings produced from the brood lots selected as the best were also selected for hardiness, resistance to disease, conversion of food, rapid growth, ... About 1 percent of the total eggs available were eventually retained for brood stock. Other lots of eggs produced fish that were used for field survival studies in lakes and streams where they were compared with non-selected stock.

Since the fish produced from the stock being developed were to be used for planting in lakes and streams, an attempt was made to develop a stock adapted to these environmental conditions. During the interval 1932–1950, the brood stock was reared and developed in ponds supplied with water from the Cedar River. New facilities became available in September 1950 (Van Cleve, 1952), after which time the water supply came from Lake Union.

A number of species of fish live in Lake Union and the connecting Lake Washington watershed. A coarse gravel filter prevents fish and large organisms from entering the water supply, but disease organisms are not filtered out; our stocks of fish, therefore, are exposed to a variety of diseases. The water intake from the lake is at about the 6-foot level; thus the extreme fluctuations in water temperatures range from 39° F. in the winter to 74° F. in summer. The average monthly temperatures for the past 5 years are recorded in Table 1.

Many of the real advantages gained by selective breeding are difficult to measure. The improved quality of the fish is very obvious to those who have worked with the problems over a number of years. Other areas of improvement, such as increased growth rate and increased egg production, are simply matters of record.

The 4-year-old brood fish used to initiate the experiments in 1932 had an average weight at spawning of 1½ pounds. During the years of selection the growth rate increased to such an extent that fish of 1½ pounds, or more, were produced in 1 year.

The improvement in the growth and egg production of selected stock is shown by Table 2 which gives the lengths and average number of eggs for various age classes. The fish of the 1953 year class at 22 months of age from spawning had an average weight of 1,848 grams, or 4.1 pounds, and their average fork length was 49.6 centimeters, or 19.5 inches. The 1952 brood-year fish at 34 months of age averaged 3,004 grams, or 6.6 pounds, with a fork length of 59.9 centimeters, or 23.6 inches. Growth of the 1951 brood-year fish was inferior to that of the 1952 brood-year select stock, for at 46 months they had an average weight of 2,092 grams, or 4.6 pounds, and a fork length of 54.2 centimeters, or 21.3 inches.

The individual fish of the select stocks were weighed and measured periodically (Figs. 1 and 2). The length-weight data obtained from such a series of measurements are presented on logarithmic scale in Figure 3. The regression of length (L) on weight (W) for the maturing male rainbow trout measured January 1955 is $\log W = 2.589 \log L - 1.155$, and for the females, $\log W = 2{,}828 \log L - 1{,}547$.

Since the fish were selected for years on the basis of growth and fecundity, it is of interest to express the relationship of the length of the fish to the number of eggs produced. This relationship (Fig. 4) is almost linear on a logarithmic plot. For each inch of increase in length there is on the average an increase of 230 eggs.

The number of eggs produced at each successive spawning increased with the age of the fish. Fish of the 1951 brood year, spawning for the

TABLE 1.—*Temperature of water (F.°) in the brood ponds at the experimental hatchery, University of Washington*

Year	January	February	March	April	May	June	July	August	September	October	November	December
1951												
Minimum	42.0	42.0	41.0	49.0	56.0	61.0	....	64.0	61.0	52.0	47.0	41.0
Maximum	48.0	47.0	49.0	56.0	67.0	69.0	....	73.0	69.0	62.0	53.0	48.0
Average	45.9	45.3	45.5	52.9	60.7	65.0	....	69.5	64.3	57.0	50.0	44.5
1952												
Minimum	39.0	41.0	42.0	44.0	46.5	58.5	64.5	64.0	63.0	54.0	45.0	43.0
Maximum	43.5	43.5	45.0	55.0	64.5	66.0	74.0	74.0	70.0	63.5	55.0	47.0
Average	40.9	42.5	43.5	50.0	56.6	62.6	69.5	69.1	65.6	59.1	50.1	44.3
1953												
Minimum	44.0	44.0	43.5	44.0	50.5	57.0	63.5	61.0	56.0	54.5	50.5	46.0
Maximum	46.5	46.0	47.0	52.0	58.5	62.0	70.0	67.0	67.0	59.0	54.0	50.0
Average	45.2	44.8	45.2	48.3	54.2	59.2	67.5	63.5	62.4	56.7	52.4	48.4
1954												
Minimum	42.5	44.0	46.0	48.0	51.5	52.0	57.0	55.0	60.0	51.0	49.0	45.0
Maximum	48.0	48.0	49.5	53.0	57.0	60.0	65.0	65.0	64.0	61.0	54.0	50.0
Average	45.4	46.5	48.2	50.0	54.7	56.8	61.9	58.7	61.4	56.3	52.6	48.1
1955												
Minimum	45.0	45.0	46.0	48.5	51.0	54.5	58.0	58.0	....	....	....	....
Maximum	48.0	49.0	50.0	53.0	57.5	66.0	64.5	65.0	....	....	....	....
Average	46.5	46.1	48.0	50.8	54.4	60.3	61.3	61.9	....	....	....	....

TABLE 2.—*Size at spawning and number of eggs produced by selected rainbow trout brood stock*

Spawning year	Age at recorded spawning	Number of females spawned	Fork length (centimeters)		Number of eggs from each female at spawning	
			Average	Maximum	Average	Maximum
1944	2	12	36.3	39.0	1,653	2,121
1946	2	39	41.9	48.0	2,011	2,982
1948	2	78	41.2	50.0	1,958	3,094
1950	2	129	35.5	45.5	1,315	2,697
1952	2	51	40.9	45.0	2,145	3,810
1953	2	27	38.9	43.5	2,032	3,631
1954	2	47	44.6	51.5	2,377	3,960
	3	36	50.5	57.0	4,042	6,106
1955	2	28	50.7	56.5	3,894	5,123
	3	28	59.6	67.0	5,029	8,850

first time in the spring of 1953, produced an average of 2,032 eggs; in their second spawning in the spring of 1954, the average production of eggs was 4,042; in the third spawning, as the fish reached the end of their fourth year—the age of initial spawning of the unselected stock used to develop this strain—the average egg production had increased to 4,985 eggs.

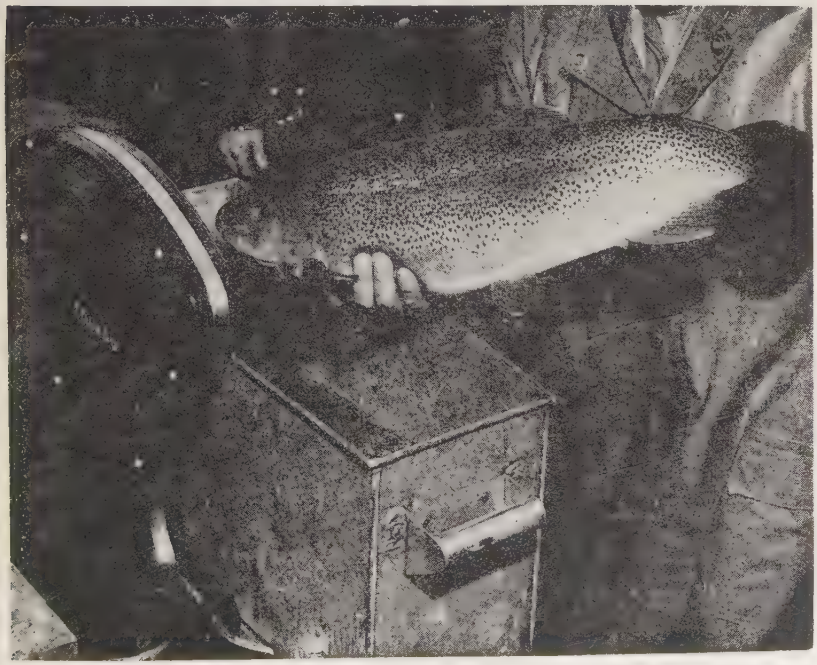

FIGURE 1.—Weighing a 34-month-old female rainbow trout of the select stock.

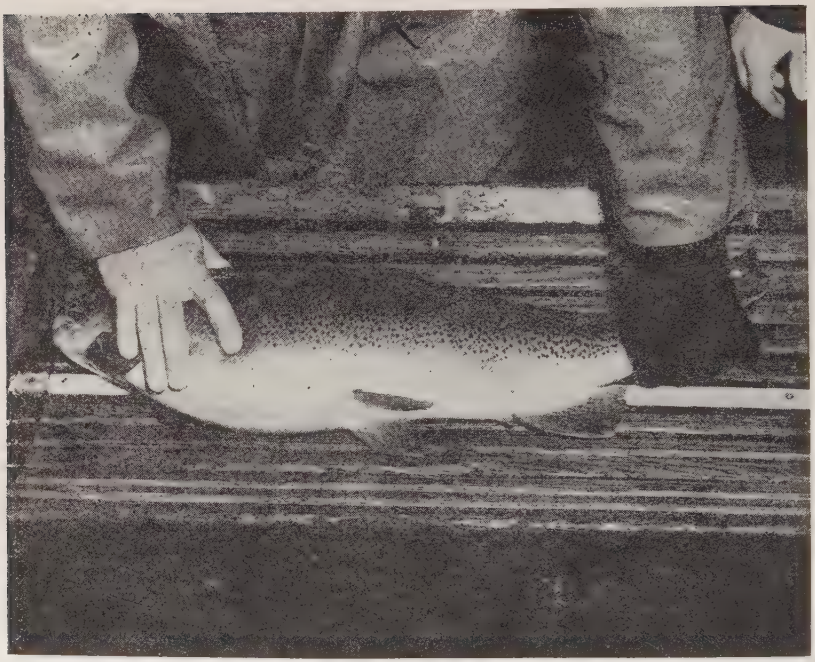

FIGURE 2.—Length determination of female rainbow trout prior to spawning.

The selections have been based in part on fecundity; those lots of eggs with maximum number and highest survival have been retained for subsequent brood stock. Fish of the 1942 brood year were the first of this stock to reach maturity in their second year. In the spring of 1944, the average egg production was 1,653 eggs and the maximum egg production 2,121 eggs. In the spring of 1955, fish of this age class had an average egg production of 3,894, with a maximum output of 5,123 eggs for a single female.

The highest yield obtained to date was 8,850 eggs from a rainbow trout in her third year, spawning for the second time. This fish weighed 10 pounds and was 26.4 inches long.

Some of the questions which might be raised are, how long should selection of brood stock continue; what are the objectives; how can the peak be determined. The experience of animal breeders has been that there is no terminal point, and that constant effort must be made to develop stocks best suited to the ever-changing environmental conditions, the needs of management, and the whims of the sportsmen who bear the cost.

Figure 3.

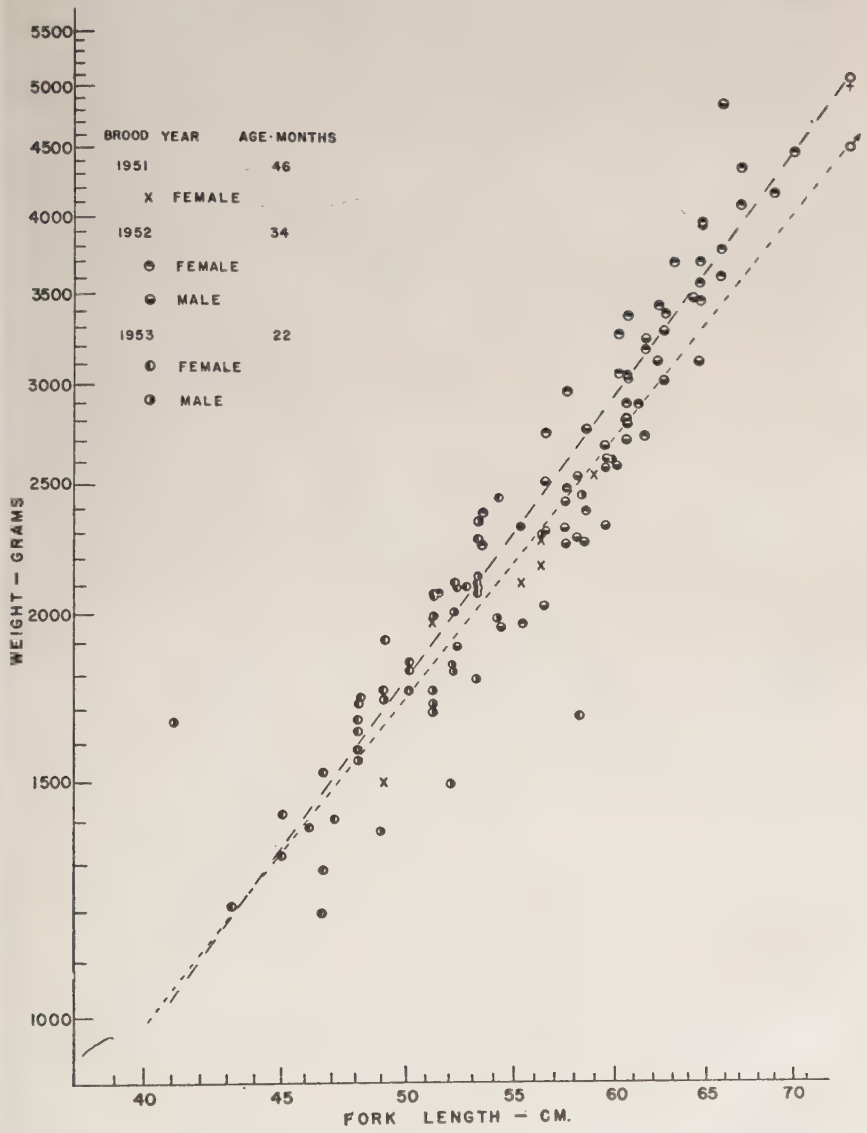

FIGURE 3.—Length-weight relationship (plotted on logarithmic scale) of three age classes of select rainbow brood stock, prior to spawning January 1955.

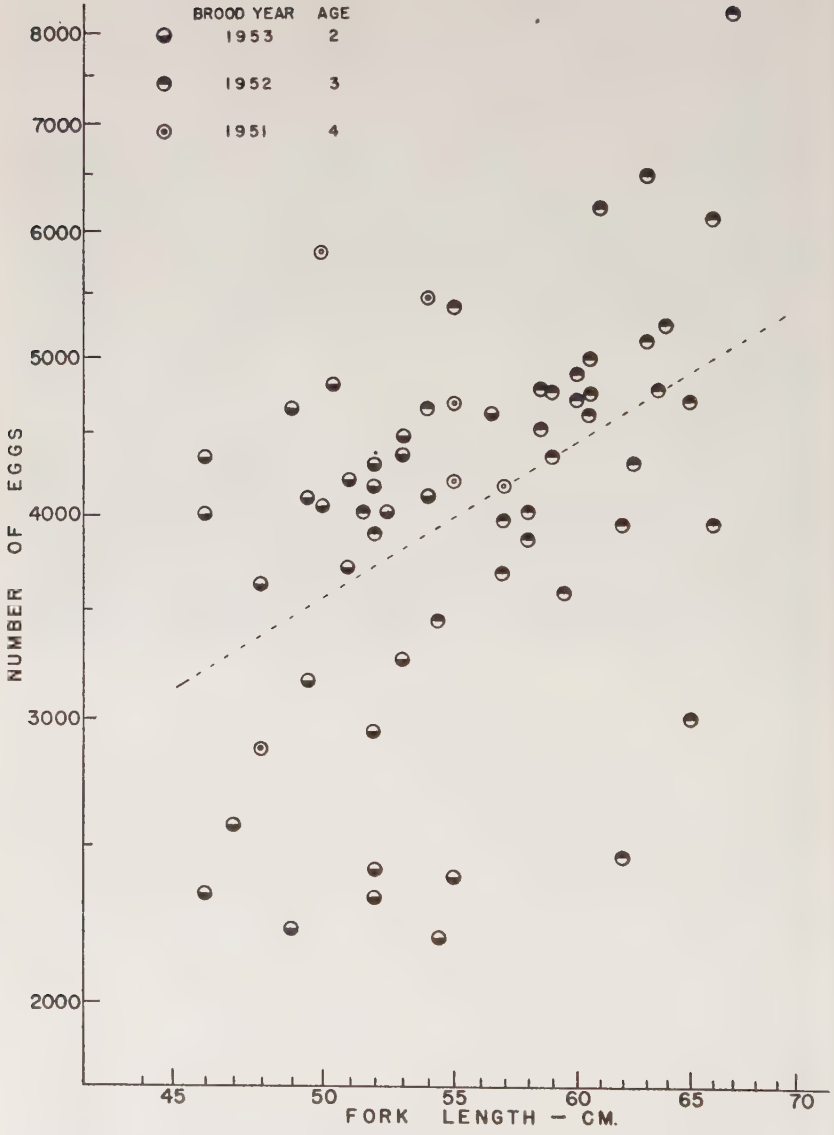

FIGURE 4.—Length-fecundity relationship on logarithmic scale of three age classes of select rainbow trout spawned February-March 1955.

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THE NEAR EXTINCTION OF LAKE TROUT IN LAKE MICHIGAN

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ABSTRACT

After the collapse of the commercial fishery for lake trout (*Salvelinus namaycush*) in Lake Michigan in the late 1940's, the further decline of the population was traced by records of numbers of small lake trout (mostly 11 to 16 inches in total length and 3 to 5 years old) caught in small-mesh nets of the chub (*Coregonus* [= *Leucichthys*] spp.) fishery. By 1951 the estimated abundance of these lake trout in lower Lake Michigan was only about 4 percent of their abundance prior to the invasion of the sea lamprey (*Petromyzon marinus*). This remnant of the population declined severely in subsequent years to a point near extinction by 1955. In April–July 1955 only 8 lake trout were caught in 5½ million linear feet of gill net.

Statistics of the lake trout and chub fisheries in State of Michigan waters of Lake Michigan for the years 1929–1954 give no indication that the destruction of small lake trout in the chub fishery had any effect on the later abundance of lake trout of commercial size, or that this destruction was a significant factor in the collapse of the lake trout fishery.

Lake trout were brought near extinction by lethal attacks of the sea lamprey and by the near or perhaps complete failure of natural reproduction in 1949 and subsequently.

Comparisons in 1949 and 1950 of numbers of legal-sized lake trout caught in large-mesh nets with numbers of small fish taken in chub nets showed that both large and small lake trout declined over the same period, and that by these years the decline may have been greater among small than among legal-sized fish.

INTRODUCTION

The decline of the commercial fishery for lake trout in Lake Michigan during the late 1940's was reported by Hile, Eschmeyer, and Lunger (1951). These authors demonstrated clearly that overfishing was not responsible for the decrease and held that the major cause of the catastrophe was the parasitic sea lamprey.

The decrease that led to a 95-percent drop in the annual commercial catch between 1944 and 1949 continued at an accelerated pace in the following years (Table 1). The take was reduced to only 3,500 pounds in 1952 and 34 pounds in 1955. The rate of decline in production was accentuated by a decrease in fishing intensity after lake trout abundance became so low that operations were unprofitable. Nevertheless, the change from an annual production of more than 6,000,000 pounds per year to one of less than 100

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pounds within little more than a decade indicates a prodigious decrease in numbers of lake trout of legal size [2] in Lake Michigan.

After commercial fishing for lake trout had practically ceased by the early 1950's, the only convenient source of information on the decline of the population was from records of the numbers of small lake trout captured in small-mesh (mostly 2½ inches, extension measure) gill nets of the chub fishery, a fishery which expanded tremendously after the collapse of lake trout production (Hile and Buettner, 1955). The present paper traces the 1951–1955 decline of this remnant of the lake trout population to a point near extinction.

TABLE 1.—*Commercial production of lake trout in Lake Michigan, 1944-55*[1]

[Thousands of pounds]

Year	Production	Year	Production
1944	6,498	1950	54
1945	5,437	1951	11
1946	3,974	1952	3
1947	2,425	1953	[2]
1948	1,197	1954	[3]
1949	342	1955	[4]

[1]Data for 1944-1949 from Hile, Eschmeyer, and Lunger (1951)
[2]402 pounds [3]107 pounds [4]34 pounds

MATERIALS AND METHODS

Materials for this study were obtained principally from reports of cooperating commercial fishermen in representative Lake Michigan ports, who maintained daily records of the number of lake trout caught in their chub nets in 1951–1955. In most of 1952 and in 1953–1955, the average depth at which each gang of nets was fished was also given. Data on the locality and the amount of gear fished were obtained either from the fisherman or from his monthly production reports to the conservation department of the state in which he operated. Records were collected by mail or in person at bi-monthly intervals, from June 1951 to December 1953 for all months during which nets were lifted, but in 1954 and 1955 the work was confined largely to the months April-July.[3] During periodic visits with operators, biologists accompanied boats to make supplemental observations. Agreement between observed and reported data proved the reliability of the fishermen's reports. Catch records were available for more than 55 million linear feet of net during the 5-year study; this gear was lifted by

2 Legal size is 1½ pounds in Illinois and Michigan waters and 17 inches, total length, in Wisconsin. For practical purposes the two limits may be considered equivalent. Since most measurements in this paper are in terms of length, "legal size" as used here indicates a total length of 17 inches.

3 Data for earlier years as well as year-round records for fishing off Two Rivers, Wisconsin, in 1925–1930 (Van Oosten and Eschmeyer, 1956) demonstrated that April–July data would provide dependable estimates of changes in abundance of lake trout. The shorter index period seemed desirable in order to reduce the inconvenience to cooperating fishermen of maintaining the daily records.

13 fishermen situated at 11 ports in 4 states. Ports represented were: Manistique, Frankfort, Pentwater, Grand Haven, and St. Joseph, Michigan; Michigan City, Indiana; Waukegan, Illinois; and Racine, Port Washington, Sheboygan, and Sturgeon Bay, Wisconsin (Fig. 1). Most fishing was within 35 miles of the home port.

Records were compiled for each fisherman in terms of the average number of lake trout caught per 1,000 linear feet of gill net lifted from each 10-fathom depth interval in each month. Similar records for the experimental fishing of the research vessels *Fulmar* (1930–1932) and *Cisco* (1954–1955) provided contrasts between populations of small lake trout in Lake Michigan before and after the invasion of the sea lamprey.

Abundance of Small Lake Trout in Lake Michigan

Sources of variability in estimates of abundance.—The various factors influencing data on abundance of lake trout collected in small-mesh gill nets off different ports and in various regions of Lake Michigan were discussed in detail by Van Oosten and Eschmeyer (1956). They found differences in abundance of lake trout in three principal geographic regions of the lake—the east and the west shores of lower Lake Michigan, and northern Lake Michigan (north of a line from Frankfort, Michigan, to Algoma, Wisconsin). Such geographic differences persisted in 1951–1955; therefore, the data were separated according to the region of the lake in which they were collected.[4] Most geographic variations in abundance that occurred within these regions were not large. The one area that differed sharply from other parts of the same region of the lake (the Sheboygan Reef) has been treated separately. In most comparisons, records were compiled for each month of collection because the data showed rather strong and consistent seasonal trends in catch. The 1930–1932 records proved that depth of fishing had a marked effect on the number of lake trout caught. No appreciable difference was observed in bathymetric distribution of lake trout in 1952–1955, as compared to 1930–1932. Consequently some comparisons of catch per unit of effort were restricted to records of nets lifted from similar depths. Analysis of the 1952–1955 data revealed, however, that the range of depths fished by chub fishermen during the same months of different years were similar, and that the effect of variations in fishing depth on comparisons of abundance in successive years was relatively unimportant. It was accordingly possible to use with confidence the data for 1951 and early 1952, for which depth records were not available, in making estimates of annual changes in lake trout abundance.

Other factors that influenced the catch per unit of effort to an unknown degree were: the material from which nets were manufactured, mesh size, and fishing time (nights out). These factors probably had little effect on comparisons among the years 1951–1955, when most nets were of 2½-

4 In the analysis of data for 1951–1955, data on fishing immediately north of the Frankfort-Algoma line, off Sturgeon Bay, Wisconsin, and Frankfort, Michigan, were combined with records for lower Lake Michigan.

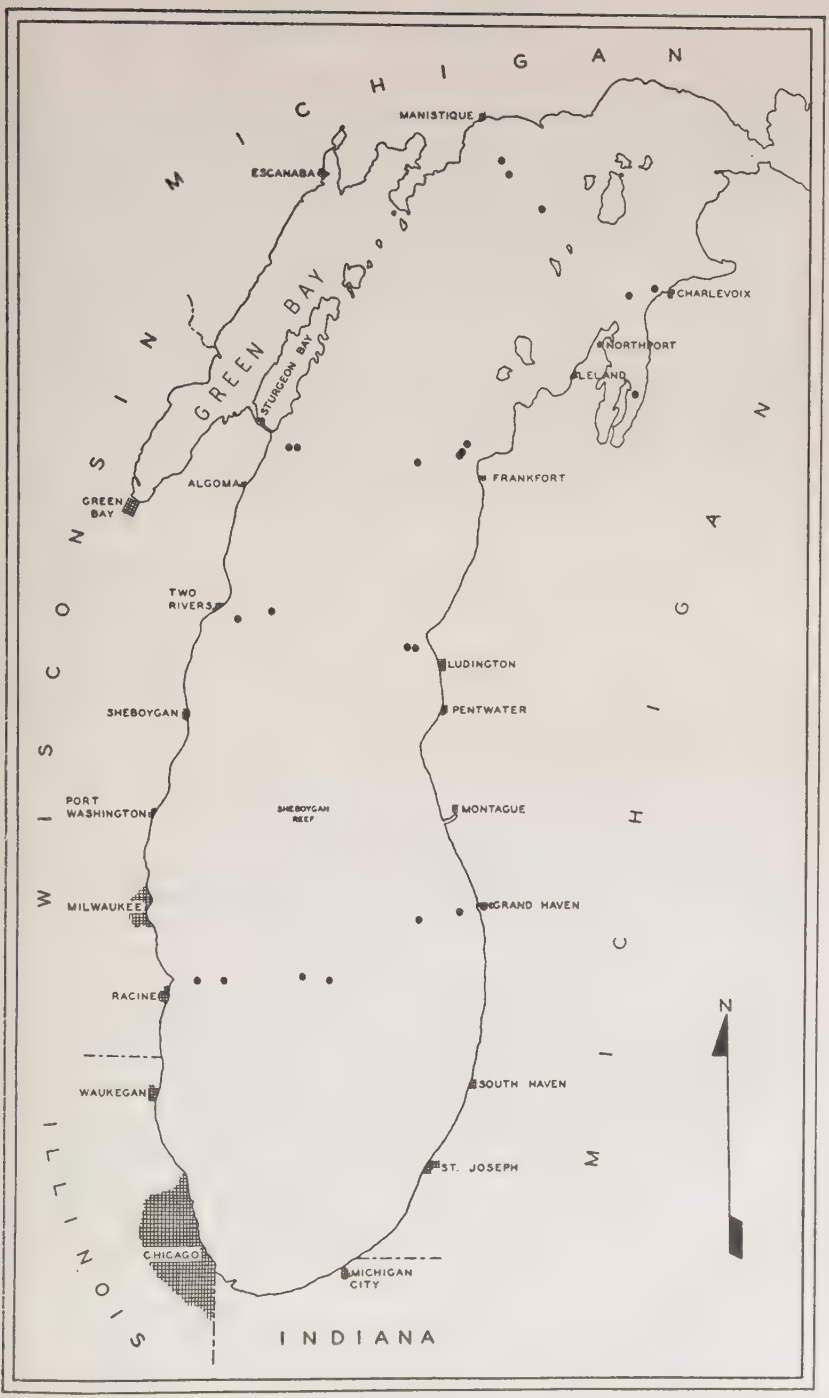

FIGURE 1.—Lake Michigan, showing localities of special interest in this study. The dots are fishing stations of the research vessel *Cisco*, 1954 and 1955.

inch-mesh nylon [5] and were fished for an average of about 7 nights (mean fishing time for 63 commercial lifts observed by biologists in 1950–1952). They did, however, bias to some degree comparisons between data for 1930–1932 and those for 1951–1955. Experimental nets fished in 1930–1932 were made of linen, had meshes from 2⅜ to 3 inches and were fished for an average of about 11 nights in 1930–1931 and 6 nights in 1932. A precise estimate of the relative efficiency of linen and nylon twine in taking lake trout is not offered, but it is certain that nylon is the more effective. In the capture of chubs it is estimated to be 2 to 3 times as efficient as cotton (Hile and Buettner, 1955) and cotton, in turn, is more effective than linen. In comparisons of data for 1930–1932 and 1951–1955, therefore, the figures for the earlier period must be recognized as underestimates.

In the 1930–1931 experimental fishing in lower Lake Michigan, nets of 2½-, 2⅝-, and 2¾-inch mesh took somewhat larger numbers of lake trout than did the 2⅜- and 3-inch-mesh nets. The differences were so small, however, that a combination of data for all mesh sizes was considered justified.

In general, the various biasing factors listed have no significant effect on the conclusions to be drawn from the data of the present paper. The changes in lake trout abundance after the invasion of the sea lamprey were so extreme that the small defects of the data can be termed trivial.

Decrease in abundance of lake trout in lower Lake Michigan.—The average numbers of lake trout caught per 1,000 feet of chub net lifted by commercial fishermen declined progressively each year from 1951 to 1955 along both shores of Lake Michigan (Table 2 and Fig. 2 [6]). Comparisons of the rate of capture during the same months of successive years show an annual decrease for each value, with the exception of February 1953 on the east shore and of July, August, and November 1952 on the west shore. In both regions these exceptions to the trend were inconsequential. The 1952 data for the months indicated reflect a slight increase over 1951 in the rate of capture of lake trout off Waukegan. This local increase was not shown by fishing at any other port.

The catch per unit of effort for lake trout in 1951, when the rate of capture in chub nets was appreciably greater than in subsequent years, was only a small fraction of that in experimental gill nets of the *Fulmar* in 1930–1931. Estimates of the changes in abundance over the several years of this study (Table 3) show that catch per unit of effort in 1951 was only 3 to 4 percent of that of 1930–1931. The number of fish in this remnant of the lake trout population declined severely in each succeeding year. The greatest recent change in abundance took place in 1954, when drops of 83 and 93 percent occurred. Although the percentage decrease was even greater in 1955, lake trout of a size vulnerable to small-mesh nets had practically disappeared by 1954. In the first 7 months of that year (a

5 A conversion from the use of cotton to nylon twine in the chub fishery was under way during the early years of this period. The change, begun in 1946, was complete or nearly so in most ports by 1952 or 1953 (Hile and Buettner, 1955).

6 Values for 1955 were too small to warrant inclusion in the figure.

TABLE 2.—*Numbers of lake trout caught per 1,000 feet of small-mesh gill net in lower Lake Michigan, 1930-1931 and 1951-1955*

[Number of thousands of feet of gill net in parentheses]

Month	East shore						West shore					
	[1]1930-31	1951	1952	1953	1954	1955	[1]1930-31	1951	1952	1953	1954	1955
January	.....	....	....	0.48	....	....	.....	....	0.62	0.19	0.01	....
	.....	....	....	(8)	....	....	.....	....	(428)	(898)	(216)	....
February	.....	....	0.38	0.50	0.00	....	.....	....	0.42	0.10	0.05	....
	.....	....	(72)	(86)	(29)	....	.....	....	(951)	(331)	(240)	....
March	.....	....	1.72	1.03	0.03	....	.....	....	0.39	0.22	0.05	....
	.....	....	(236)	(454)	(227)	....	.....	....	(805)	(418)	(263)	....
April	.....	....	2.03	0.95	0.12	0.01	.....	....	0.48	0.35	0.04	[2]0.00
	.....	....	(377)	(799)	(892)	(527)	.....	....	(756)	(407)	(1,027)	(802)
May	12.42	....	0.91	0.69	0.06	[2]0.00	12.51	....	0.32	0.12	0.03	0.00
	(46)	....	(652)	(910)	(1,078)	(501)	(51)	....	(1,189)	(458)	(1,249)	(875)
June	11.33	0.97	0.36	0.22	0.02	0.00	7.68	0.40	0.18	0.07	0.01	0.00
	(44)	(280)	(992)	(1,518)	(1,064)	(542)	(97)	(459)	(924)	(1,130)	(450)	(718)
July	18.34	0.61	0.24	0.05	0.01	[2]0.00	5.65	0.12	0.22	0.04	[2]0.00	0.00
	(89)	(686)	(1,072)	(2,043)	(1,536)	(644)	(79)	(1,250)	(1,047)	(1,208)	(523)	(906)
August	19.90	0.39	0.26	0.06	....	....	4.12	0.07	0.09	[2]0.00	....	....
	(76)	(925)	(1,139)	(649)	....	....	(138)	(1,019)	(1,001)	(240)	....	....
September	17.25	0.31	0.19	0.06	....	....	5.41	0.23	0.07	0.00	....	....
	(37)	(496)	(936)	(518)	....	....	(59)	(560)	(988)	(264)	....	....
October	15.60	0.71	0.32	0.18	....	....	6.05	0.21	0.11	0.00	....	....
	(31)	(441)	(573)	(622)	....	....	(99)	(552)	(753)	(276)	....	....
November	.....	....	....	....	....	....	9.99	0.07	0.11	....	....	....
	.....	....	....	....	....	....	(79)	(205)	(97)	....	....	....
December	.....	....	0.39	[2]0.00	....	....	.....	0.62	0.23	[2]0.00	....	....
	.....	....	(336)	(230)	....	....	.....	(510)	(467)	(216)	....	....

[1]Data from Van Oosten and Eschmeyer (1956)
[2]Less than 0.005.

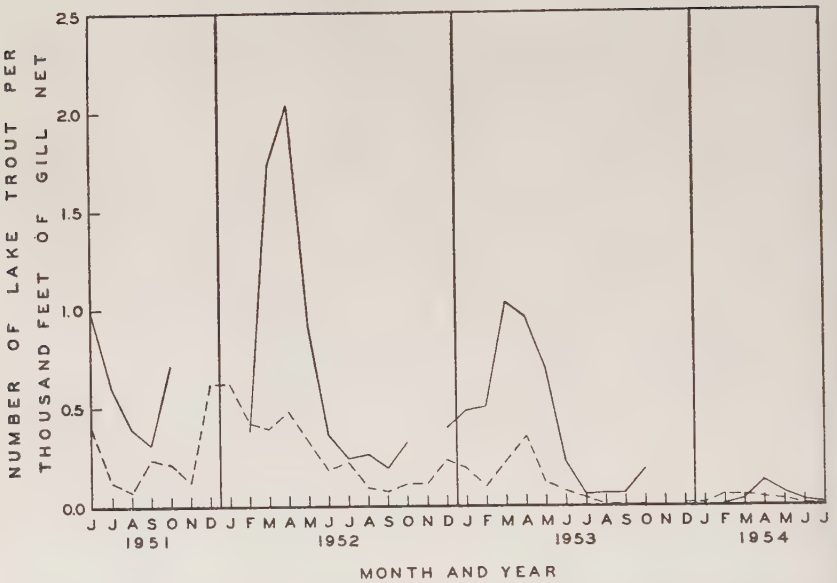

FIGURE 2.—Numbers of lake trout caught per 1,000 feet of small-mesh gill net lifted in Lake Michigan, 1951–1954. Solid line, east shore; dotted line, west shore.

period which includes the months when catch per net reached its seasonal peak in 1952 and 1953), 8,794,000 feet (1,666 miles) of gill net (data for east and west shores combined) took only 326 lake trout; in April–July 1955 only 8 lake trout were caught in 5½ million feet of gear.

In the graphical representation of the disappearance of lake trout in Lake Michigan (Fig. 2) both the annual downward progression of lake trout numbers and seasonal changes in catch per net during each year are

TABLE 3.—*Percentage decreases in abundance of lake trout in lower Lake Michigan, based on catches in small-mesh gill nets*

[Comparisons are restricted to those months during which fishing was done in both of the years compared. The number of monthly averages included in each comparison is shown in parentheses]

Region	Years compared				
	1930-31 and 1951	1951 and 1952	1952 and 1953	1953 and 1954	1954 and 1955
East shore	96 (5)	54 (5)	45 (10)	93 (6)	94 (4)
West shore	97 (6)	41 (7)	65 (11)	83 (7)	98 (4)

well defined. Curves of seasonal availability on both shores of the lake show a tendency toward a gradual rise to a peak in March or April, followed by a decline to the seasonal low in July, August, and September, and a gradual rise during the last quarter of the year. These annual and seasonal changes were still apparent when the data were stratified according to depth. They were present also in the records of individual operators.

Differences between lake trout abundance in 1930–1931 and in later years are demonstrated strikingly by the computation of the numbers of lake trout that would have been taken in each recent season if the rate of capture had been equal to that of experimental gill nets fished in 1930–1931 in the same region of the lake, month, and 10-fathom depth interval (Table 4). In 1952, for example, the "expected" catch of lake trout in

TABLE 4.—*Comparison of numbers of lake trout caught in commercial chub nets in lower Lake Michigan, 1952-1955, with numbers that would have been taken in the same nets if the rate of capture had been equal to that of experimental gill nets fished in 1930-1931*

[Included (bottom of table) is a comparison of experimental fishing in 1930-1931 and 1954-1955]

Year and kind of net	Thousands of feet of net	Expected catch[1] (number)	Actual catch	
			Number	Percentage of expected catch
Commercial				
1952	8,853	103,462	2,542	2.5
1953	7,889	96,957	1,347	1.4
1954	4,401	49,829	106	0.2
1955	3,193	35,026	2	[2]0.0
Experimental				
1954	57	827	2	0.2
1955	96	995	0	0.0

[1]Computed on the basis of fishing records of the *Fulmar* in 1930-1932 for the same region of the lake, 10-fathom depth interval, and month; from Van Oosten and Eschmeyer (1956)

[2]Less than 0.05

8,853,000 feet of gill net lifted in lower Lake Michigan was 103,462; the actual catch was only 2,542 or 2.5 percent. The percentage of the expected catch actually taken decreased progressively each year through 1955, when over 3 million feet of gear took only 2 fish, as compared with an expected catch of 35,026. The sharp decline in lake trout numbers from 1953 to 1954 is again clearly shown in Table 4, as it was in Tables 2 and 3.

Data on experimental fishing in Lake Michigan by the *Cisco* in 1954–1955 corroborate the data from the commercial fishery. In 1954, 57,000 feet of small-mesh gill net with an expected catch of 827 lake trout took only 2 fish; 96,000 feet of net lifted in 1955, which had an expected catch of 995 fish, took none. Of the gear lifted in 1954, 41,000 feet were linen, identical in construction and mesh size (2⅜ to 3 inches) to nets used by the *Fulmar;* 16,000 feet were nylon, with mesh sizes of 2¼ to 3 inches. In 1955, 68,000 feet of linen and 28,000 feet of nylon net (the latter with mesh sizes ranging from 2 to 3 inches) were lifted.

In addition to the gill-netting operations by the *Cisco* in 1954 and 1955, otter trawls were dragged along the bottom over a wide range of depths, dates, and localities. No lake trout were caught during a total effective fishing time of 33 hours in 1954 and 9 hours in 1955 (capture of other species of fish proved that the trawl was operating satisfactorily).

Decrease in abundance of lake trout on the Sheboygan Reef.—A remarkable winter and spring concentration of lake trout on the Sheboygan Reef, an area approximately 30 miles east of Port Washington, Wisconsin, with water depths of about 25 to 40 fathoms, was revealed by the records of a fisherman operating in these waters during the years 1948–1955 (Table 5). Fishing throughout the 8-year period for which data are shown was within an 8-mile radius.

The rate of capture of lake trout in chub nets was much higher on the Sheboygan Reef than in other areas in the lake in 1951 and 1952. Throughout the years 1948–1952, and as recently as February 1953, catches were strongly reminiscent of the fishing success of experimental nets fished by the *Fulmar* in 1930–1931, before the sea lamprey had invaded Lake Mich-

TABLE 5.—*Numbers of lake trout caught per thousand feet of 2½-inch-mesh gill net on the Sheboygan Reef, Lake Michigan, 1948-1955*[1]

[Number of thousands of feet of net in parentheses]

Year	February	March	April	May
1948	18.2 (32)	16.6 (42)	8.5 (53)	....
1949	19.7 (127)	16.5 (190)	9.8 (236)	6.8 (106)
1950	....	20.7 (106)	15.2 (185)	12.3 (106)
1951	10.6 (26)	14.6 (106)	12.1 (290)	7.2 (53)
1952	8.9 (92)	6.4 (373)	2.7 (197)	0.7 (106)
[2]1953	8.3 (211)	3.4 (271)	1.3 (42)	....
1954	0.7 (106)	0.3 (317)	0.4 (190)	....
1955	[3]0.0 (123)	[3]0.0 (317)	0.0 (169)	0.0 (211)

[1]For the years 1948-1953 the pounds (dressed weight) of lake trout given in monthly commercial fishing reports to the State of Wisconsin were multiplied by the factor 1.86 to obtain the values shown in the table. The average round weight of 2,147 lake trout caught in 2½-inch-mesh gill nets in lower Lake Michigan in 1930-1931 was 10.5 ounces (Van Oosten and Eschmeyer, 1956). The average loss of weight after dressing of 135 lake trout caught in 2½-inch-mesh nets lifted on the Sheboygan Reef March 3, 1953, was 18.3 percent. Values for 1954 and 1955 were supplied directly by the fisherman

[2]Catch in January 1953 was 16.1 lake trout per 1,000 feet in 84,000 feet of net. No fishing was done in this month during other years

[3]Less than 0.05

igan. In 1950, when the rate of capture of lake trout was highest, the estimates of catch per 1,000 feet of gill net for March to May ranged from 20.7 to 12.3. An annual decline began in 1951 and the catch decreased in subsequent years during each month for which records were available, until it was practically nil in 1955. The most significant decrease in this area, as elsewhere in the lake, occurred in 1954, when the catch dropped nearly 90 percent, from 4.3 lake trout per 1,000 feet of gill net in 1953 to 0.5 in 1954 (simple averages of values for 3 months). Lake trout continued to be more plentiful on the Sheboygan Reef in early 1954 than elsewhere in Lake Michigan, but the numbers vulnerable to small-mesh nets had, nevertheless, decreased drastically since the previous year. By early 1955 small lake trout were as rare in this former center of abundance as they were elsewhere in Lake Michigan.

Decrease in abundance of lake trout in northern Lake Michigan.—The data on catches of lake trout in chub nets in northern Lake Michigan (Table 6) were obtained from records of a single operator who fished periodically out of Manistique. Except for part of 1952, depth data are not available, and no records at all were obtained in 1953 or 1955.

TABLE 6.—*Numbers of lake trout caught per 1,000 feet of small-mesh gill net in northern Lake Michigan, 1932-1954*

[Number of thousands of feet of gill net in parentheses]

Month	[1]1932	1951	1952	1954
January	....	....	....	0.00
	....	....	....	(152)
February	....	....	....	0.00
	....	....	....	(410)
March	....	....	0.18	0.00
	....	....	(261)	(86)
April	....	....	0.20	....
	....	....	(480)	....
May	....	....	0.03	....
	....	....	(442)	....
June	5.57	0.26	0.04	....
	(129)	(238)	(266)	....
July	3.30	0.17	0.10	....
	(199)	(525)	(176)	....
August	9.07	0.99	....	....
	(199)	(538)	....	....
September	1.86	0.11	....	....
	(93)	(406)	....	....
October	....	0.05	....	....
	....	(402)	....	....

[1]From catch records of experimental gill nets fished by the *Fulmar*

Despite the scantiness of the data, they support the conclusions based on records for lower Lake Michigan. The catch per unit of effort in 1951 was a small fraction of that for the experimental nets of the *Fulmar* in 1932; the take declined further in 1952; and in 1954 not one lake trout was caught in 648,000 feet of gill net.

Belief that the lake trout is nearing extinction in northern as well as in southern Lake Michigan is supported by the experimental fishing of the *Cisco* in 1955. Only 1 lake trout was caught in 62,000 feet of small-mesh experimental linen and nylon gill net.

TABLE 7.—*Percentage length-frequency distribution of lake trout caught in 2½-inch-mesh gill nets in Lake Michigan, 1930-1952*

[Data for 1930-31 and 1932 are from Van Oosten and Eschmeyer (1956). Dates, localities, and (in parentheses) numbers of fish composing other collections in lower Lake Michigan were as follows: 1950 — June 10-29, Frankfort, Pentwater, and Ludington (238) and August 22-25, Grand Haven and St. Joseph (54); 1952 — April 23, Michigan City (56), April 28-30, Port Washington, Sheboygan, and Sturgeon Bay (45), and May 5, Frankfort (15). Data for northern Lake Michigan in 1950 were collected at Charlevoix and Manistique, June 9-July 15. See Fig. 1 for locations]

Total length (inches)	Lower Lake Michigan			Northern Lake Michigan	
	1930-1931	1950	1952	1932	1950
8.0- 8.9	0.1	....	....	....	....
9.0- 9.9	....	0.7	....	....	....
10.0-10.9	1.2	1.7	4.3	....	0.9
11.0-11.9	15.4	24.7	18.1	4.2	10.3
12.0-12.9	38.6	32.9	24.1	26.2	17.8
13.0-13.9	26.9	18.8	22.4	31.0	24.3
14.0-14.9	10.1	9.3	12.1	19.3	18.7
15.0-15.9	3.8	5.2	8.6	11.1	15.4
16.0-16.9	1.7	4.8	4.3	3.8	8.4
17.0-17.9	1.0	1.0	3.5	2.4	2.8
18.0-18.9	0.4	0.3	1.7	1.0	1.4
19.0-19.9	0.1	0.3	....	0.4	....
>19.9	0.7	0.3	0.9	0.6	....
Number of fish	1,826	292	116	1,007	214
Average length (inches)	13.5	13.1	13.5	13.9	14.0

FACTORS IN THE DECLINE OF LAKE TROUT IN LAKE MICHIGAN

Three factors which require consideration in an appraisal of the cause of the near extinction of lake trout in Lake Michigan are: the destruction of lake trout in the small-mesh nets of the chub fishery; the destruction of lake trout by the sea lamprey; and the near or perhaps complete failure of natural reproduction of lake trout by 1949 or 1950. To treat these factors effectively it is necessary to have some knowledge of the size and age of lake trout taken in chub nets.

The modes of the length-frequency distributions of lake trout caught in 2½-inch-mesh nets in lower Lake Michigan in 1930–1931, 1950, and 1952 were at the 12.0- to 12.9-inch interval; average lengths ranged from 13.1 to 13.5 inches (Table 7). In northern Lake Michigan, the mode was at 13.0–13.9 inches in both 1932 and 1950; the mean lengths were 13.9 and

14.0 inches, respectively. For each of these years, and in both regions, 76 to 91 percent of the lake trout were within a 4-inch interval of length (11.0–14.9 inches in lower Lake Michigan and 12.0–15.9 inches in the northern region).

Van Oosten and Eschmeyer (1956) reported that 4-year-old fish composed 54 percent of 127 lake trout caught in 2½-inch-mesh gill nets in 1930–1932; fish of age-group III made up 25 percent, and the V group, 14 percent. Comparison of their age determinations for 575 lake trout and of Cable's (1956) records for 738 small lake trout caught in 1947–1951 (Table 8), with the length-frequency distributions (Table 7), support the view that these age groups must have been the principal ones caught in chub nets.

TABLE 8.—*Average total lengths (inches) of lake trout collected in Lake Michigan*

Years of collection	Length at end of year of life[1]						
	1	2	3	4	5	6	7
1930-1932	3.4	7.1	11.7	13.0	14.4	16.8	18.6
1947-1951	5.6	8.6	10.9	13.3	15.8	17.8	....

[1]The data for 1930-1932 are based on both calculated and actual measurements (Van Oosten and Eschmeyer, 1956); lengths for 1947-1951 were obtained by the summation of calculated increments, for marked hatchery trout released in Lake Michigan as fingerlings in the fall of 1944, 1945, and 1946, and recovered in 2½-inch-mesh gill nets (Cable, 1956)

Destruction of small lake trout in chub nets.—The results of experimental fishing of the *Fulmar* in 1930–1932 (Tables 2 and 6), and other observations, demonstrated clearly that, during years of normal abundance, large numbers of small lake trout were killed by the small-mesh nets of the chub fishery. Statistics of the commercial fishery for State of Michigan waters of Lake Michigan in 1929–1954, however, give no indication that this loss had any effect on the later abundance of lake trout (Table 9).

Fluctuations in the intensity (and thus the potential destructiveness) of the chub fishery and later changes in abundance of lake trout were not correlated. In 1935–1938, a period of high fishing intensity in the chub fishery, the estimated number of small lake trout caught in State of Michigan waters ranged from 688,000 to 927,000. These estimates were the highest for any years in the period 1929–1947, and in 3 of the years (1935, 1936, 1938) greater numbers of lake trout were estimated to have been killed in the chub fishery than were caught in the commercial fishery for lake trout of legal size. Nevertheless, in 1939–1944, within the period when this destruction should have had its maximum effect in reducing the number of fish available to the commercial fishery, trout production in State of Michigan waters averaged 2,802,000 pounds per year—a value higher than for any equivalent period in the years 1929–1953. The abundance index for lake trout in 1939–1944 ranged from 100 to 126 percent of the 1929–1943 average.

TABLE 9.—*Estimated numbers of lake trout caught in the chub fishery and in the lake trout fishery in State of Michigan waters of Lake Michigan, 1929-1953*

Year	Chub fishing		Commercial production of lake trout		Abundance index of lake trout[5]
	Units of 10,000 feet of small-mesh gill net lifted[1]	Potential number of lake trout caught (thousands)[2]	Thousands of pounds[3]	Thousands of individuals[4]	
1929	3,234	380	2,198	733	87
1930	3,229	372	2,556	852	83
1931	2,234	273	2,652	884	87
1932	1,735	225	2,746	915	96
1933	1,615	196	2,379	793	97
1934	3,632	424	2,053	684	98
1935	7,355	922	2,451	817	102
1936	7,609	927	2,127	709	97
1937	5,656	688	2,264	755	93
1938	6,957	864	2,480	827	92
1939	4,920	674	2,778	926	105
1940	1,491	191	2,780	927	100
1941	1,734	206	3,189	1,063	123
1942	1,806	214	2,641	880	114
1943	1,487	209	2,814	938	126
1944	1,453	167	2,609	870	110
1945	2,767	321	2,228	743	98
1946	2,786	337	1,908	636	75
1947	4,188	576	914	305	60
1948	6,452	924	589	196	50
1949	7,604	1,017	223	74	26
1950	6,508	876	25	8	.....
1951	6,701	867	2	1	.....
1952	7,266	965	.....	.....	.....
1953	8,551	1,121	.....	.....	.....
1954	8,556	1,150	.....	.....	.....

[1]From Hile and Buettner (1955)

[2]Based on average numbers of lake trout caught in experimental gill nets by the *Fulmar* in 1930-1932 (Van Oosten and Eschmeyer, 1956). These averages were 54 per 10,000 feet of net in northern Lake Michigan and 165 in State of Michigan waters of lower Lake Michigan

[3]Data for 1929-1949 from Hile, Eschmeyer, and Lunger (1951)

[4]Average weight in the commercial catch in the Great Lakes suggested by Van Oosten (1944) was from 3 to 10 or 12 pounds. The smallest value was used in converting from pounds to numbers of individuals

[5]Percentage of 1929-1943 mean

In 1940–1944, in contrast, the intensity of fishing for chubs was markedly lower than in 1935–1938; the potential numbers of small lake trout destroyed ranged from 167,000 to 214,000 per year, the lowest values in the period 1929–1954 (except 1933). In these years only 19 to 24 percent as many trout were estimated taken in the chub fishery as in the lake trout fishery. However, the lake trout fishery collapsed in the late 1940's, when the fishery should have benefitted most from the decreased destruction of small lake trout in the chub fishery of 1940–1944.

The statistics of the chub and lake trout fisheries in State of Michigan waters of Lake Michigan, therefore, give no indication that the catch of small lake trout in the chub fishery had any effect on the later abundance of lake trout of commercial size. It was not a significant factor either in the collapse of the lake trout fishery or in the recent scarcity of small trout. In

so far as is known, the sea lamprey was primarily, and perhaps solely, responsible for the near extinction of lake trout in Lake Michigan.

The destruction of lake trout by the sea lamprey.—The action of the sea lamprey in bringing lake trout of Lake Michigan near to extinction was twofold. First, the stock was reduced directly by lethal attacks of the parasite on the trout. Second, recruitment to the stock diminished and most probably came to an end when spawning stocks decreased so that natural reproduction became less and less effective. It is not possible to estimate precisely the relative importance of the two factors for any calendar year. It can, nevertheless, be demonstrated that enormous declines took place in the abundance of lake trout well in advance of the time when failure of natural reproduction could have been a factor and also to offer evidence that by 1949 or 1950 little spawning was taking place.

The tracing of the decline of lake trout was handicapped by the necessary change from records of catch per unit of effort in commercial trout gear (most production from large-mesh gill nets) to the records of small fish caught in chub gill nets. The decline in abundance of lake trout during the late 1940's made trout fishing so unprofitable that fishing intensity also underwent a rapid decline (Table 10). By 1950 the levels of production and fishing effort were so low that the routine estimation of abundance was

TABLE 10.—*Production and abundance of lake trout in Lake Michigan, 1943-1950*

Year of spawning	Production of lake trout		Abundance index of lake trout in State of Michigan waters[2]	Index of fishing intensity for lake trout in State of Michigan waters[2]	Year when young were 4 years old
	Thousands of pounds[1]	Percentage of 1940-1944 mean			
1943	6,860	104	126	88	1948
1944	6,498	99	110	92	1949
1945	5,437	83	98	87	1950
1946	3,974	60	75	91	1951
1947	2,425	37	60	61	1952
1948	1,197	18	50	50	1953
1949	342	5	26	26	1954
1950	54	1	..	..	1955

[1]Data for 1943-1949 from Hile, Eschmeyer, and Lunger (1951)
[2]Percentage of 1929-1943 mean

abandoned. Subsequent to 1949, therefore, information on abundance of lake trout had to come almost exclusively from records of small trout in chub nets obtained by field observers or submitted by cooperating fishermen.

Inasmuch as large- and small-mesh gill nets capture lake trout of different sizes, the question arises as to whether the rates of decline of large and small lake trout were the same or at least similar. If they were, records from chub nets can be used to extend to more recent years the description of the decline of lake trout that Hile, Eschmeyer, and Lunger (1951) were able to carry through 1949 from statistics on the trout fishery. Information on this question, although not plentiful, indicates strongly that

declines in abundance of legal-sized trout and of small trout of the size caught in chub nets followed similar courses. The first of the recent records on catches of small lake trout in chub nets in Lake Michigan was obtained in May 1949 by biologists who observed the lifting of 160,000 feet of small-mesh gill net off Frankfort, Michigan. These nets contained 228 lake trout or 1.4 fish per 1,000 feet. Nets lifted in 1930–1931 by the *Fulmar* in the same region of the lake, in the same month, and from the same depth, took 20.4 per 1,000 feet. The abundance of small lake trout off Frankfort in 1949, therefore, was only 7 percent of that in 1930–1931. In the same year the abundance index for legal-sized trout in the Frankfort district was 35 percent of the 1929–1943 mean (the index was 79 in 1930 and 71 in 1931). According to these figures the decline in abundance of lake trout off Frankfort by 1949 was more severe among small than among legal-sized fish.

Field observations of 1950 agreed with those of 1949. In June–August 1950, biologists observed catches in 324,000 feet of chub nets along the east shore between Charlevoix and St. Joseph, Michigan. The average catch of 1.0 trout per 1,000 feet was only 4 percent of the rate in *Fulmar* nets fished under comparable conditions. Information on the abundance of legal-sized lake trout in 1950 is limited to that obtained from observations on 128,000 feet of large-mesh net lifted off Frankfort, Charlevoix, and Manistique, Michigan, June 7–July 15. The total catch of 136 pounds of legal-sized fish represented a rate of capture of 8 percent of the 1929–1943 average. In 1950, as in 1949, therefore, both legal-sized and small lake trout were extremely scarce, and again the abundance of small fish was relatively lower than that of large ones.

The 1949 and 1950 observations indicate that large and small lake trout both declined over the same general period of years and that by these years the decline may have been greater among small fish.

The low level of abundance of small lake trout in 1949 and 1950 and the subsequent annual decreases to 1954 are believed to be largely the direct result of lethal attacks by sea lampreys. Failure of natural reproduction is held first to have exerted a major influence in 1954. Arguments in support of this view are based on evidence as to the abundance of spawners in the calendar years that contributed the dominant age group of later years, on the sudden drop in the catch of small trout in 1954, and on the sudden rise in 1954 in the percentage of legal-sized lake trout in the chub-net catches.

The statistics of Table 10 on the production of legal-sized lake trout in all of Lake Michigan and on their abundance in State of Michigan waters provide a fair measure of the abundance of spawners in different calendar years. This measure is not perfect, however, because not all legal-sized fish are sexually mature (Table 11). The fish examined in 1947 included numbers of immature lake trout of both sexes larger than the minimum legal sizes of 17 inches (Wisconsin) and 1½ pounds (Illinois and Michigan). Furthermore, the percentages of immature fish at various lengths undoubtedly would have been much greater if the samples had not come from spawning or pre-spawning aggregations which normally are domin-

ated by mature individuals.[7] Because the smaller legal-sized lake trout include immature fish, the percentage of spawners among legal-sized fish must vary with fluctuations in the size distribution. The extent of such annual fluctuations is not known, but in 1948, as in 1947, large fish were plentiful in the catch.

If the data of Table 10 are accepted as indicative of general trends of abundance of mature lake trout, substantial numbers were present and were caught through 1948. In that year the catch in the entire lake was

TABLE 11.—*Length distribution of lake trout collected in Lake Michigan, 1947-1948*

[In 1947 fish were collected October 9-23 in 4½-, 5-, and 5¼-inch-mesh gill nets off Frankfort, Montague, South Haven, and St. Joseph, Michigan, and Waukegan, Illinois; 1948 collections were on September 22-October 8 in 4½-, 4¾-, 5-, and 5¼-inch-mesh gill nets off Charlevoix, Leland, and Northport, Michigan, and Waukegan. Sex and maturity were not determined in 1948]

Total length (inches)	Year of collection							
	1947							1948
	Males			Females			Total number of fish	Total number of fish
	Immature	Mature	Percentage mature	Immature	Mature	Percentage mature		
<17.0	1	...	0	4	...	0	5	76
17.0-17.9	1	...	0	4	...	0	5	47
18.0-18.9	2	...	0	3	1	25	6	39
19.0-19.9	3	2	40	3	1	25	9	39
20.0-20.9	2	20	91	8	...	0	30	56
21.0-21.9	2	102	98	8	7	47	119	56
22.0-22.9	..	133	100	18	37	67	188	51
23.0-23.9	1	94	99	9	70	89	174	42
24.0-24.9	..	79	100	7	91	93	177	43
25.0-25.9	..	50	100	1	62	98	113	38
26.0-26.9	1	26	96	..	35	100	62	25
27.0-27.9	..	7	100	..	22	100	29	20
28.0-28.9	..	3	100	..	6	100	9	23
>28.9	..	...	...	[1]1	7	88	8	33
Total	13	516	...	66	339	...	934	588

[1]This non-spawning female was 31.2 inches long. The 7 mature fish were 29.7 to 34.3 inches in length

still well above a million pounds and the abundance index in State of Michigan water was 50 percent of the 1929–1943 mean. Fish from the 1948 spawning hatched in 1949 and could be expected to dominate chub-net catches of lake trout as age-group IV in 1953. Although conditions in 1948 can hardly be termed good, they were much worse in 1949. Production dropped 71 percent and the abundance index (26) was barely half that of 1948. Further deterioration occurred in 1950.

The evidence from Table 10 that natural reproduction may have become largely ineffective in 1949 is not in itself conclusive. It is supported, how-

[7] Lake trout in lower Lake Michigan matured at a much smaller size than in southern Lake Superior (Eschmeyer, 1955) or western Lake Ontario (Dymond, 1928). In fish from spawning or pre-spawning aggregations collected in southern Lake Superior, September 8-November 8, 1950, most males less than 24 inches and females less than 27 inches long were immature.

ever, by the tremendous drop in the catch of lake trout in chub nets (Tables 2–4) from 1953 when the normally dominant IV group came from the 1948 spawning to 1954 in which year IV-group fish came from the 1949 spawning. Further evidence of sparse recruitment in 1954 is provided by the following record of the percentage of legal-sized lake trout in the catch of chub nets, made available by cooperating fishermen of Michigan City Indiana, and St. Joseph, Michigan:

Year	*Number of fish*	*Percentage legal-sized*
1951	1,113	5
1952	1,616	9
1953	1,749	15
1954	153	52
1955	4	75

The percentage of legal-sized lake trout increased gradually from 5 in 1951 to 15 in 1953 but in 1954 it rose sharply to 52. In view of the far lower vulnerability of legal-sized than of smaller fish to chub gill nets, the predominance of the larger lake trout in southeastern Lake Michigan in 1954 was actually much greater than this percentage indicates.

The evidence that the decline of lake trout of all sizes down to those captured in chub gill nets was caused primarily by lethal attacks of sea lampreys and that failure of natural reproduction was of minor importance until 1954, after the major decline had occurred, makes possible the explanation of the correlation between the size of lake trout and the percentage of individuals bearing sea lamprey scars. The relationship described by Van Oosten (1949) between the length of Lake Michigan trout and the percentage of individuals with scars is typical of that observed repeatedly in lake trout populations subject to sea lamprey predation. In Van Oosten's samples the percentage of scarred fish was small (0.5 percent) among fish less than 17 inches long but rose rapidly and consistently with increase in length of fish to a value of 80.0 percent for lake trout 24.5 to 35.4 inches long. Although Van Oosten did not undertake an explanation of this relationship, the alternatives are obvious. Either sea lampreys attack lake trout selectively, favoring the larger fish, or the ability of trout to survive lamprey attacks increases with size of fish. The data of the present study favor overwhelmingly the second explanation. Especially pertinent is the evidence that the abundance of small lake trout apparently decreased more rapidly than that of legal-sized individuals.

An increase in ability to survive sea lamprey attacks with increase in size of fish may explain also the relation between scarring and the length of white suckers described by Hall and Elliott (1954).

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POPULATIONS OF SPOTTED SUNFISH AND FLORIDA LARGEMOUTH BASS IN A CONSTANT-TEMPERATURE SPRING [1]

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Abstract

Populations of spotted sunfish, *Lepomis punctatus punctatus* (Valenciennes) and Florida largemouth bass, *Micropterus salmoides floridanus* (LeSueur) have been studied in the fertile biotic communities of Silver Springs, Florida. This large limestone spring has a constant temperature, nearly constant chemical environment, and stable biological communities, but a seasonal change in light intensity and general productivity. Studies of the scales of these two species have shown rings which are possibly rhythmic but not related to temperature. Strong rings in spotted Sunfish are apparently too numerous to be annuli and their formation is not correlated with the time of year. The spotted sunfish population reproduces mainly in spring and summer, although there is evidence for some scattered winter breeding. Age groups do not stand out distinctly in length-frequency diagrams. Reproduction by Florida largemouth bass appears to be chiefly limited to spring and summer. Thus, even with a constant temperature, there are apparently cycles in the life history of these fishes which cause the periods of increased reproduction to coincide with periods of greater food production. Recaptures of tagged bass and measurements of spotted sunfish in cages within the springs indicated moderate growth rates. Tagging with individual color combinations for visual study indicated little movement by the spotted sunfish, but a high mortality. Data are included on the length-weight and body-scale relationships, degree of scale regeneration, and food. The seasonal activities of centrarchid populations are adjusted to make use of the maximum flow of productive energy in spring and summer and are thus correlated with the photoperiodic cycle.

Introduction

Although the fluctuations in chemical and physical properties of most aquatic environments are large and irregular, an intricate adjustment may develop between the environmentally controlled primary production of organic matter by plants and the growth and reproduction of fish. The mechanisms by which the fish populations are self-regulated to maintain these adjustments are thus pertinent to the management of fisheries. Annulus formation, annual fluctuations in population size, changes in growth rate, and periodicity of breeding are examples of phenomena which must be adjusted to basic energy flows in the community. Unfortunately,

1 These studies were aided by a contract between the Biology Branch, Office of Naval Research, Department of the Navy, and the University of Florida, NR 163–106.

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it is often difficult to isolate the exact role played by internal rhythms and external controlling factors in situations where many changes are occurring simultaneously. If one could ideally contain a natural community of fishes under constant limnological conditions some insight might be gained as to the role played by single factors.

The conditions in Silver Springs, Marion County, Florida, one of the large springs near the center of the state, are nearly ideal for "natural experimentation." A large outflow of hard water from limestone caverns maintains a continual stream with a constant temperature of 73° F. and a constant chemical state. In this rich and clear medium, the subtropical sun maintains a dense community of organisms with a high degree of stability. Among external influences only the factors of light intensity and day length change seasonally. Odum [4] found that primary production in December is about one-third of that in May. A special state law prohibits fishing in Silver River, which is used mainly as a recreational attraction. The communities of the headwater zone (20 acres) are somewhat isolated by 4 miles of a more swift and turbulent section of the river that begins about a mile below the first spring.

A general account of Silver Springs with evidence of physical and chemical stability is provided by the Florida Geological Survey (Ferguson *et al.*, 1947). Qualitative and quantitative descriptions of the communities of mainly eel grass (*Sagittaria*), invertebrates, fishes, community trophic structure, metabolisms, limnological characteristics, and productivity have been provided by Odum.[5] The algae were described by Whitford,[6] and the fishes by Hubbs and Allen (1944).

The purpose of this paper is to report some studies on the fish populations in this unusual environment. The investigation was begun by Odum with the assistance of W. C. Sloan in 1953 as part of a general productivity study. Systematic collections and tagging were initiated in March 1954 by Odum and Caldwell, continued through that summer by Berry, until June 1955 by Caldwell and Hellier, and completed by the group in the summer of 1955. A total of 34 trips were made with the generous assistance of volunteers.[7]

Although other centrarchids are present in the spring (Hubbs and Allen, 1944), most of the data were obtained on the spotted sunfish and the Florida largemouth bass, which are by far the most abundant fishes in their respective roles as carnivore and top carnivore. Some idea of the dominance of centrarchids among the larger fish can be obtained from visual estimates in which 68 percent of 2,287 fishes counted were sunfishes and bass

4 Odum, Howard T. 1953. Productivity in Florida springs. Progress report to the Office of Naval Research. [Processed]

5 Odum, Howard T. 1953, 1954, 1955. Productivity in Florida springs. First, second, third, and fourth progress reports to the Office of Naval Research. [Processed]

6 Whitford, Larry A. 1954. The species of algae and their distribution in Florida Springs. In: Productivity of Florida springs. Third semi-annual report to the Office of Naval Research. [Processed]

7 Mrs. F. Berry, J. Campos, R. Crossman, Mrs. T. Hellier, W. Hook, J. Howell, Mrs. D. Hynes, D. Hynes, M. Huish, J. McCrone, D. Wilder, R. Winslow, and J. Yount.

Studies elsewhere on closely related centrarchid fishes in waters with seasonal changes permit comparisons that show the effect of the nearly constant environment in Silver Springs. To further such comparisons, efforts have been made to determine population characteristics in spite of the relatively small samples necessitated by the small area, restricted collecting privileges, and the lack of a fishery. Data are reported by species in sections on spawning, length-weight relationships, length-frequency distributions (spotted sunfish only), growth rings on scales, and growth rates.

Methods

Most of the fish were taken with a 25-foot bag seine of ½-inch stretched mesh. Some of the larger specimens were collected with a spear gun and a small cast net. The current flow (0.1 to 1.0 meter per second), deep channel (3 to 7 meters), clear water (horizontal underwater visibility, 105 meters), and obstructions such as logs, presented some unusual problems, especially since all work had to be done at night to insure a more representative sample and in order not to interfere with the glass-bottom boats. Gill nets, trot lines, and traps were tried but were relatively unsuccessful. Seining in the shallows along the edges of the run and boils of the spring in beds of eel grass yielded the only reasonably satisfactory samples. Heavy plant beds and soft bottoms made even this fishing difficult.

The fish that were not tagged were preserved in the field in 10-percent formalin; measurements, weights, and scale samples were taken in the laboratory. Those fish tagged were measured and a scale sample was taken before return to the water. Standard lengths were measured in millimeters and weights in grams. Scales were placed between glass slides in a 2- by 2-inch lantern slide projector and examined on a screen at a magnification of × 21. Lengths from scale measurements were calculated graphically by direct proportion (Carlander and Smith, 1944).

Spotted Sunfish

Maturity and spawning.—Although Hubbs and Allen (1944) reported this species to spawn only in April and June, the absence of distinct modes in frequency distributions (Fig. 1), the presence of young fish in most months, and the appearance of at least a few ripe adults (Fig. 2) at all times of the year suggest that spotted sunfish breed most of the year in Silver Springs. Similar breeding was reported by Kilby (1955) for this species at Bayport, Florida, in a brackish-water community fed by the run of the large freshwater Weekiwachee Springs. Studies by Sloan (1956) on this run indicate a relatively small seasonal variation of temperature. Carr (1947), reported only a late-spring spawning for spotted sunfish in "ordinary Florida streams", but had made no definite search for winter spawning. McLane [8] observed breeding activity in other Florida springs

[8] McLane, William M. 1955. The fishes of the St. Johns River system. Ph.D. Dissertation, University of Florida.

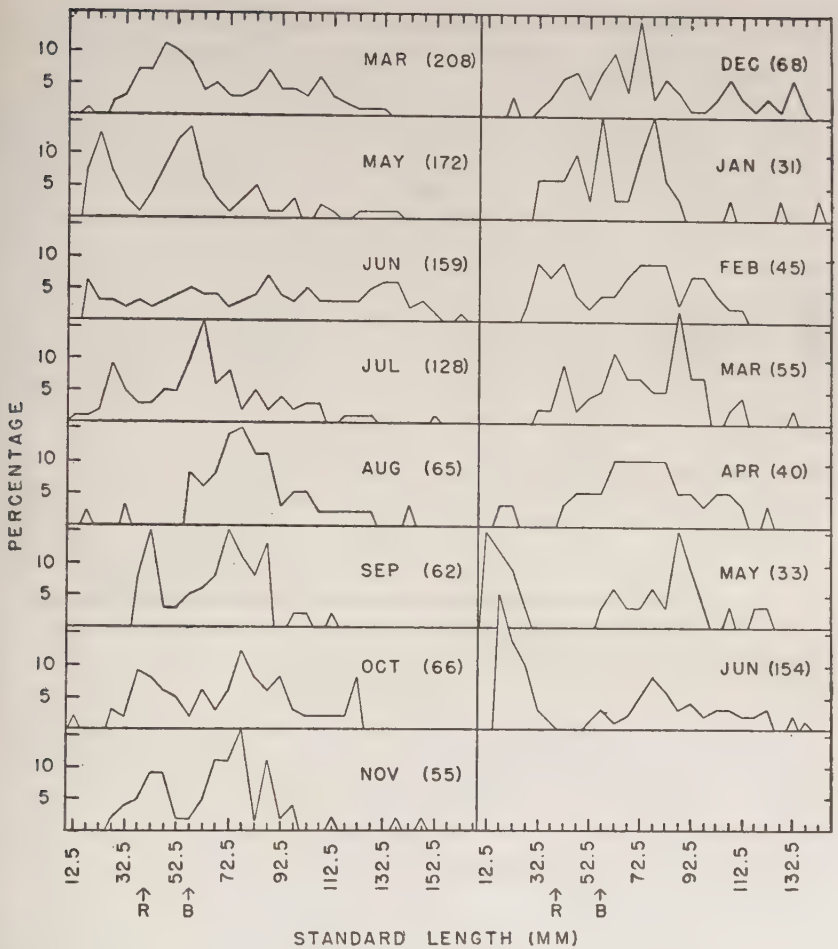

FIGURE 1.—Frequency distribution (standard length) of the spotted sunfish from March 1954 through June 1955. The small arrow lettered "R" indicates the mean calculated standard length at which the first scale ring was formed. The small arrow lettered "B" indicates the standard length of the smallest fish with ripe gonads.

between March 25 and September 9. There may thus be a correlation between a long period of spawning of this species and nearly constant temperatures.

Spawning activity increased greatly, however, during the summer in Silver Springs, and winter spawning was limited (Fig. 2). It was observed also that spotted sunfish begin breeding at a small size. Ripe gonads were found in one 55-millimeter fish. Carr (1947) observed a 2-inch (approximately 51 millimeters) fish extruding eggs. In Silver Springs no develop-

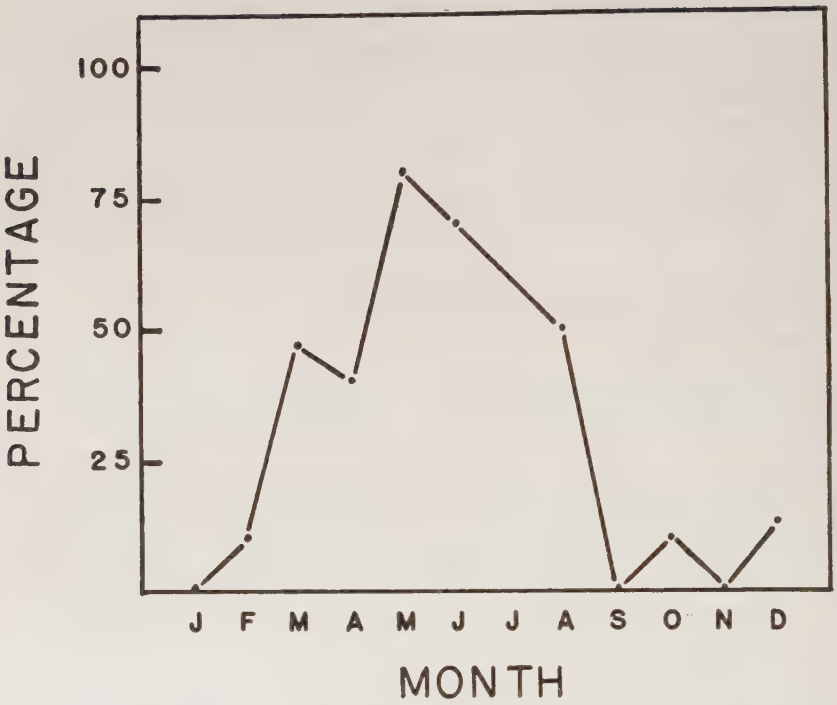

FIGURE 2.—Percentage of spotted sunfish with well-developed gonads in different months. Each point is based on 10 or more individuals with standard lengths 65 millimeters or above.

ing gonads were found in a sample of 30 fish between 40 and 55 millimeters from March and July.

Length-frequency distribution.—The length-frequencies for the spotted sunfish by month (Fig. 1) reveal no distinct separation of groups. The presence of small fish in most months and other evidences of breeding cited earlier indicate a steady replacement to the population. Odum [9] offered evidence of a high degree of community stability in Silver Springs. If the populations of centrarchids are also relatively stable, it is possible that a close balance exists between replacement and mortality.

The seining introduced some size selection. The smallest fish are hard to find in the rolls of plants and readily escape the seine by edging into the muck at the base of the grass. Many of the largest fish escape by swimming around the wings of the net. The total sampled catch contained maximum numbers in the 35- to 69-millimeter size range. On a weight basis, however,

9 Odum, Howard T. 1955. Productivity in Florida springs. Progress report to the Office of Naval Research. [Processed]

the population is greatest at the 70- to 104-millimeter size, where greater weight per individual offsets the decreasing number of individuals.

The length-frequencies for March give some suggestion of a peak at 47 millimeters. This peak moves to the right for several months at a rate (0.2 millimeter per day) somewhat larger than the growth rate of the caged fish (0.12 millimeter per day) described later. During the remainder of the year there was little evidence of progression of modes due to growth.

Length-weight relation.—The relationship of standard length to preserved weight was graphed for each month of the study. The resulting length-weight regressions did not vary materially from month to month, sexes combined. In a sample of 21 individuals, fresh wet-weight was 93 percent of preserved weight. Specimens from all months were used to determine the relationship between standard length in millimeters (L) and preserved weight in grams (W) as follows:

$$\log W = -4.32 + 3.002 \log L$$

The coefficient of condition (K), or relative plumpness, was determined for the Silver Springs fish as defined by $K = W \times 10^5/L^3$. The K value for the Silver Springs spotted sunfish averaged 4.82 and varied little with size of fish (Table 1).

TABLE 1.—*Length-weight relationship of spotted sunfish from Silver Springs*
[Grouped in 5-millimeter classes]

Mean standard length (millimeters)	Weight (grams)		Calculated weight[1] (grams)	Mean K	Number of fish
	Mean	Range			
12.9	0.12	0.1– 0.2	0.10	5.59	7
17.5	0.26	0.1– 0.4	0.26	4.85	28
21.9	0.46	0.3– 0.6	0.50	4.38	36
27.4	0.9	0.5– 1.5	0.99	4.38	33
31.6	1.4	1.0– 2.1	1.5	4.44	28
37.1	2.4	1.7– 3.3	2.5	4.70	32
42.2	3.5	2.7– 4.6	3.6	4.66	49
47.0	5.1	4.0– 7.3	5.0	4.91	50
52.3	7.1	5.9– 8.2	6.9	4.96	49
56.9	9.1	7.1–12.1	8.9	4.94	72
62.2	11.6	9.5–13.6	11.6	4.82	76
67.1	14.5	11.6–17.3	14.5	4.80	53
71.9	17.8	15.1–22.5	17.9	4.79	68
76.7	21.6	18.0–27.3	21.7	4.79	59
81.4	26.0	22.0–31.4	26.0	4.82	38
87.0	31.2	27.8–38.6	31.7	4.74	28
91.8	37.5	33.3–46.9	37.3	4.85	14
97.1	46.4	43.3–52.0	44.1	5.07	9
104.0	60.0	58.3–61.7	54.2	5.33	2
107.2	58.7	55.9–62.5	59.3	4.76	6
111.5	66.2	56.8–75.3	66.8	4.78	4
116.0	80.0	.....	75.2	5.13	1
121.8	85.1	74.8– 96.1	87.1	4.71	5
127.3	95.5	78.9–109.1	99.4	4.63	3
132.5	112.4	105.2–119.5	112.1	4.83	2
137.7	130.9	120.2–142.0	125.8	5.01	3
142.0	127.1	.....	138.0	4.44	1

[1]From length-weight equation given in text

A constant ratio was found between standard and total length. Standard length may be converted to total length by multiplying by 1.27 and total length to standard length, by 0.79.

Tagging and growth in cages.—A total of 267 spotted sunfish were marked with plastic Peterson disc tags (nickel pins) or with monel-metal clamp tags. The fish marked were in the 20 acres of the ¾-mile headwater community. Spotted sunfish tagged with various color combinations were observed and identified with the aid of face masks as late as a month after marking, in the general area where tagged. Recaptures within a week after tagging were exactly in the tagging localities. However, only one spotted sunfish was retaken more than 2 weeks after tagging. This fish, marked with a Peterson tag, was at liberty 85 days (Table 2), during the fall. The fish was probably adult when tagged (142 millimeters) and showed a 3-millimeter decrease in standard length. The decrease of length may have been a result of injury due to tagging, low food production in the fall, or measuring error. The fish was recovered at the point of tagging.

Fourteen days after some intensive tagging in the Paradise Park area of the springs in late March 1954 Robert Haubrich, wearing a face mask, searched 2 hours among the plants but observed only two tagged fish.

Several explanations may be offered for the limited returns from tagging. Since fish were readily observed in the tagging areas the first few days after tagging, but were absent after a few weeks, and since intensive search did not reveal the missing tagged fish elsewhere in the spring, migration probably can be discounted. We received no reports of recovery of any of our tags downstream in the Oklawaha River outside the area of the spring and its run. This species is frequently taken by sport fishermen in an area where the Florida State Game and Fresh Water Fish Commission has conducted a number of tagging studies (waters fed in part by Silver Springs), and the public is thus educated to return tags. Sport fishing is not permitted in Silver Springs itself.

Peterson-tagged fish kept in enclosures died within 2 weeks, whereas untagged fish were kept without mortality for longer periods (Table 2). Three fish marked with metal clamp tags on the opercle and kept in cages had the following history: after 3 weeks one tag worked out and the hole was healing, one tag was producing a large sore, and the third fish had undergone a decrease in length. A high mortality, possibly accentuated by the tagging, may in part explain the low rate of tag returns.

The growth of spotted sunfish kept in hardware-cloth enclosures was measured after 2- to 3-week periods (Table 2). One fish was retained 10 months. The enclosures, 1 to 3 square meters in area, were placed over *Sagittaria* beds characteristic of the springs community in zones where a steady current passed through the cages. The size of the fish decreased in one cage but growth occurred in 2 other, more favorably situated, enclosures. The average change, included the decreases in length, indicates growth of 0.12 millimeter per day. This figure is probably an underestimate for the summer season in view of the artificial conditions in the enclosures. The figure is used, however, to interpret the ring patterns of the scales.

TABLE 2.—*Growth of individual fish, tagged or confined in enclosures*

Species and date of first measurement	Initial standard length (millimeters)	Number of days free	Increase (millimeters)		Mean[1] weight (grams)	Weight change (grams per day)	Percentage weight change per day
			Total	Per day			
Spotted sunfish							
Tagged (plastic)							
August 31, 1954...	142	85	−3	−0.035	129.5	−0.1	−0.08
Enclosures							
June 9, 1953.....	120	300	46	0.15	74.8	0.22	0.30
June 29, 1955.....	122	13	1	0.08	43.3	0.10	0.23
do.....	92	13	5	0.38	20.4	0.25	1.22
July 25, 1955.....	122	18	2	0.11	88.0	0.26	0.40
do.....	73	18	2	0.11	19.4	0.09	0.46
do.....	79	18	2	0.11	24.6	0.11	0.43
do.....	55	18	3	0.17	8.6	0.08	0.88
do.....	120	18	0	0.00	82.6	0.00	0.00
do.....	98	18	−1	−0.06	44.4	−0.07	−0.15
do.....	83	18	0	0.00	27.4	0.00	0.00
do.....	108	18	−1	−0.06	59.5	−0.08	−0.17
do.....	98	18	1	0.06	45.7	0.08	0.17
do.....	80	18	−0.5	−0.03	24.3	−0.03	−0.11
August 12, 1955...	107	12	8	0.67	65.7	1.18	1.80
do.....	98	12	2	0.17	46.5	0.25	0.53
do.....	97	12	2	0.17	44.8	0.17	0.38
do.....	79	12	1	0.13	24.6	0.15	0.61
do.....	75	12	1	0.13	20.6	0.07	0.34
do.....	58	12	0	0.00	9.3	0.00	0.00
do.....	82	12	0	0.00	26.4	0.00	0.00
do.....	97	12	2	0.17	44.8	0.17	0.38
do.....	120	12	2	0.17	83.7	0.18	0.21
Mean.....	161.9	..	.	0.12	46.0	0.13	0.309
Florida largemouth bass							
Tagged							
July 11, 1954.....	124	105	10	0.095	82.6	0.17	0.21
July 25, 1954.....	112	82	19	0.23	70.5	0.37	0.53
do.....	110	122	18	0.15	66.3	0.23	0.35
Sept. 24, 1954.....	116	21	−1	−0.05	60.1	−0.07	−0.12
do.....	120	82	4	0.05	70.2	0.08	0.11
do.....	105	96	2	0.02	47.1	0.03	0.06
Mean.....	114.5	..	..	0.08	66.1	0.135	0.19

[1]Determined from calculated weight (using the equation given in text) at initial and final measuring

Scales and growth rings.—Scales from the side of the fish were projected and measurements made of growth rings and the anterior radius on two unregenerated scales from each fish. The continuous breeding season, lack of distinct modes that would point to age groups in length-frequency distributions, and a constant high temperature make difficult the interpretation of the numerous distinct "growth rings." Thus, in order to obtain an unbiased analysis, scales were measured systematically by one observer, at first without any attempt to determine age. Only the strong rings with "cutting over" were measured; the basis for selection was the arbitrary but consistent judgment of the same observer (Hellier). In this procedure, different numbers of rings were sometimes measured on different scales from the same fish.

The anterior radius (millimeters, $\times$ 21), R, plotted against standard

length in millimeters, L, formed a pattern of points that could be fitted reasonably well to a straight line. For fish 70 to 150 millimeters long (dry scales about a year old):

$$R = -9.7 + .56\ L.$$

For fish 20 to 70 millimeters standard length (fresh scales):

$$R = .63\ L.$$

Ring measurements were converted to calculated standard lengths by direct proportion. One set of values was then obtained for each fish by averaging any two values that were similar. The first two rings on fish smaller than 70 millimeters did not appear distinctly enough on most of the larger fishes to qualify under the arbitrary "ring definition" that was used. Therefore the mean calculated standard length for the first two rings (labeled A and B) reported in Figure 3 was obtained from the small fish only. The remainder of the lengths are the means of the values computed from the first and subsequent rings on the larger fish. With this procedure, extra rings on some fishes are counteracted by omission of other faint rings. The data of regression of length on rings in Figure 3 are thus a summary of estimates from the distinct rings, obtained objectively.

In order to interpret the meaning of the rings, some idea is needed of the time between rings, although the likelihood is small that the time intervals between rings are constant. Data on growth given previously indicated that 44 millimeters per year (0.12 millimeters per day) was a minimal estimate of the possible summer growth rates of larger fish (90 to 120 millimeters, standard length). If growth ceases in winter, the rate would be half (22 millimeter per year). The movement of peaks on the length-frequency graph (Fig. 1) suggests a growth of 30 millimeters per year confined to the summer season. From the increments between rings in Figure 3, it is seen that 5 to 12 millimeters per year would need to be added for fish of this size if the rings were annuli. If this reasoning is correct, the rings are added more frequently than once a year and are not annuli.

The proximity of the last ring to the scale margin is indicated by month in Figure 4. Rings apparently are laid down in every month. An examination of small fish, 30 to 47 millimeters long, in January, May, and November showed recent formation of the first ring. Thus the formation of the first ring is related more to the size than to the season. The laying down of more than one distinct ring per year in centrarchids is well known, as described by the phrase "false annulus" (Sprugel, 1954). In the Silver Springs spotted sunfish false annuli may be the rule.

37.8 percent of the scales of this species were found to be regenerated.

Food and parasites.—The role of the spotted sunfish as both a carnivore and a herbivore in Silver Springs was indicated by a few analyses of stomach contents. Qualitatively similar wads of algae and small invertebrates were found in the smallest and largest fish and in the fish sampled from January and May. The thick beds of *Sagittaria* are covered with a

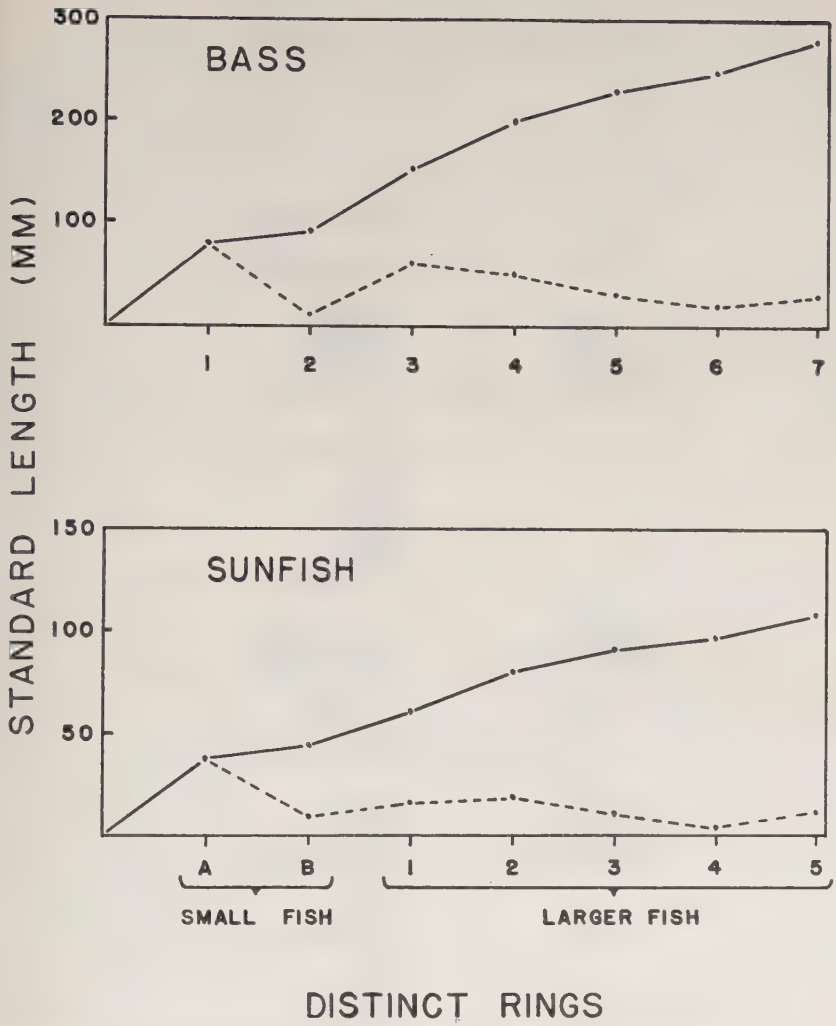

FIGURE 3.—Mean calculated standard lengths corresponding to distinct scale rings in the Florida largemouth bass and the spotted sunfish. Increments of standard length increase between rings are indicated by the broken line. The first two rings (A and B) for the spotted sunfish were obtained from scales of individuals smaller than 70 millimeters. These data were obtained without any attempt to assign annuli.

dense periphyton containing diatoms, filamentous algae, and dense invertebrate populations, especially midges and caddisflies. Gammarids and shrimps are dominant about the bases of the plants. The stomach contents resemble the periphyton. Apparently the plant and animal material is taken up to-

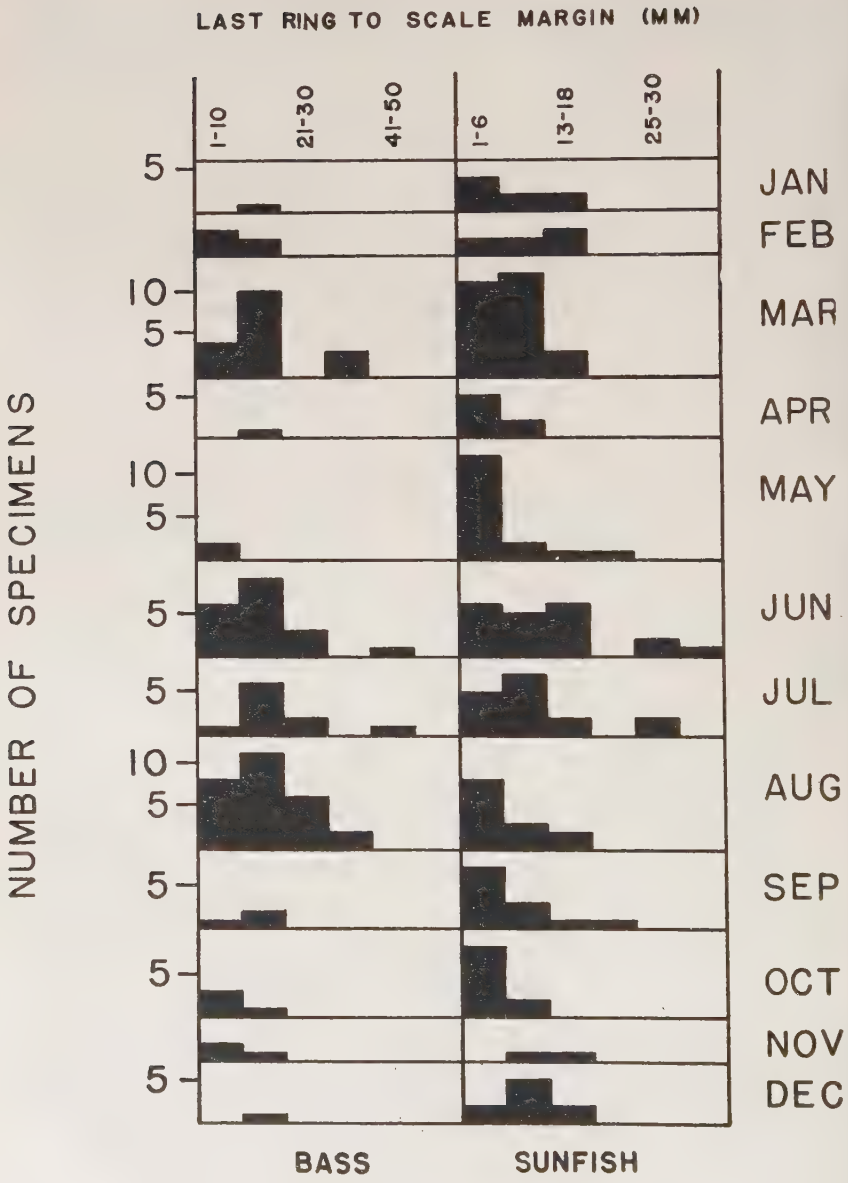

FIGURE 4.—Frequency distribution of Florida largemouth bass was spotted sunfish according to the growth increment since the last distinct scale ring. Frequency interval is 10 millimeters calculated standard length.

gether. The stomach contents of 10 fish were divided into animal and plant portions and oven-dried. The separation was not perfect because of the small size of many of the components. For December, 0.57 gram of plant and 0.16 gram of animal material were found; for May, 0.063 gram of plant and 0.033 gram of animal material. The algae are apparently passed through undigested since the filamentous materials were found in the intestines as well as in the stomach. Because the animal portions may be digested more readily than the plant portions, there is no certainty that the wads of filamentous algae in the stomach are as important to the nutrition of the spotted sunfish as their presence suggests. The diet is similar for the smallest fish. Stomachs from ten individuals less than 63 millimeters in standard length in January contained 0.071 gram of plant material and 0.30 gram of animal material.

Although no study was made, it was noted that almost every spotted sunfish opened for examination of the gonads was infested with Acanthocephala.

Florida Largemouth Bass

Tagging and growth.—The tagging was slightly more successful with the Florida largemouth bass than with the spotted sunfish. Six bass were recovered from 72 individuals tagged, (Table 2). The records suggest that growth was more rapid during the summer than in the fall. This difference would indicate a correlation between growth and plant production and thus ultimately with the light. Krumholz[10] reported seasonal growth patterns correlated more with light than with temperature.

Florida largemouth bass showed more movement than the spotted sunfish. Fish tagged with colored plastic tags were seen 2 days later ½ mile from the place of first capture, and one tagged bass was seen 2 miles downstream from the point of tagging (the color combination was not distinguished and thus the time period between tagging and observation is not known).

Length-weight relation.—Although only 53 individuals, between 18 and 242 millimeters, standard length, were weighed and measured, an approximate length-weight relationship (preserved weights) was obtained:

$$\log W = -4.5 + 2.95 \log L.$$

The length-weight relationship and coefficient of condition for different sizes of bass are shown in Table 3.

The ratio of total length to standard length remained nearly constant at 1.24 for fish 18 to 242 millimeters long.

Spawning.—Breeding activities by the Florida largemouth bass were observed in Silver Springs from February through August. Ripe gonads were found from March to September. Bass less than 25 millimeters in

[10] Krumholz, L. A. 1954. A summary of findings of the ecological survey of White Oak Creek, Roane Co., Tenn. 1950–1953. U. S. Atomic Energy Commission Technical Information Service ORO-132.

TABLE 3.—*Length-weight relationship of Florida largemouth bass from Silver Springs*
[Grouped in 10-millimeter classes]

Mean standard length[1] (millimeters)	Weight (grams)		Calculated weight[2] (grams)	Mean[3] *K*	Number of fish
	Mean	Range			
18.7	0.2	.....	0.2	3.06	3
23.4	0.3	0.2- 0.6	0.3	2.34	9
31.7	0.8	0.6- 0.9	0.8	2.51	3
44.7	2.2	1.4- 2.9	2.3	2.46	6
54.5	3.9	3.0- 4.8	4.2	2.41	2
62.3	6.0	4.8- 6.9	6.2	2.48	4
72.0	9.2	8.1–10.3	9.5	2.46	2
83.0	16.0	.....	14.5	2.80	1
94.5	23.1	20.6–25.5	21.3	2.74	2
103.5	27.5	24.0–29.2	27.8	2.48	4
122.4	44.6	41.9–47.2	45.6	2.43	5
135.0	59.4	55.7–62.9	60.9	2.41	3
141.0	72.6	.....	69.2	2.59	1
156.7	91.8	90.8–93.5	94.5	2.39	3
163.0	94.95	90.6–99.3	106.1	2.19	2
202.0	162.0	.....	199.9	1.97	1
215.0	224.5	.....	240.1	2.26	1
242.0	311.0	.....	340.5	2.19	1

[1]Length groups without representatives are omitted
[2]From length-weight equation given in text
[3]Grand average *K*, 2.45

length were taken on May 26, 1955, May 28, 1954, and June 15, 1955. This evidence suggests that the spawning by Florida largemouth bass in Silver Springs occurs at the same time as in ordinary variable-temperature environments in Florida. McLane (1948) found Florida largemouth bass smaller than 30 millimeters in the St. Johns River in April, May, and June only. If spawning takes place at other times of the year in Florida springs it is certainly limited.

Scales and growth rings.—Scales of Florida largemouth bass were treated in the manner already described for the spotted sunfish. The scale samples of this species were 42.3 percent regenerated. There is good evidence, however, that most of the rings in the bass are, on the average, annuli. The growth rate, averaging 0.083 millimeter/per day (30.3 millimeters/per year) was determined from the tag recoveries for fish 112 to 124 millimeters long. When this rate is compared with the increments between growth rings in Figure 3 (10 to 60 millimeters/per year), comparable values are found.

The irregular shapes of the curves in Figure 3 result from the objective manner of reading the scales. When some of the first rings were not measured because they were indistinct, the remainder of the rings on the fish were then included in the means of the next younger ring. Thus the regression of standard length on "distinct rings" is probably slightly steeper than the actual rate. Whether this tendency to overestimate the growth per ring is counteracted by the tendency to underestimate the growth per ring due to inclusion of spurious rings is not known. At any rate, the

method gives an objective definition of the relationship of rings and length. The curve in Figure 3 for growth per annulus (ring) falls within the range of values for some largemouth bass stocks elsewhere as summarized by Carlander (1950). The curve indicates, however, that the growth per ring in Silver Springs is less than the mean of bass growth in other localities.

Data presented by Viosca (1943, 1953) suggest that much more rapid growths occur in southern waters in successional communities where no climax of "balance" has been achieved. In Silver Springs, where a relatively high degree of stability apparently has existed, at least since the modification of the margins about 15 years ago (Hubbs and Allen, 1944), slower growth more like that in stable ponds may exist. Thus, as indicated by Viosca, when conditions are more nearly in climax the energy goes into avenues not leading to net growth of bass. This view is consistent with the general ecological idea of net production and accumulation of organic matter during succession and a balance between production and losses during climax or steady state. The high primary production of the Silver Springs community is apparently expressed as a high density (visual estimate of 2.1 centrarchids/per square meter) with moderate growth per individual.

Acknowledgments

Grateful appreciation is expressed to William Ray and William Ray, Jr., operators of Silver Springs, E. Ross Allen and Wilfred T. Neill, and the many members of their staffs who have aided this study. We owe much to the late W. C. Allee, who encouraged the work, and to William Sloan who made helpful suggestions. We wish to thank Kenneth D. Carlander for his critical examination of the manuscript.

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YIELDS OF YEAR CLASSES OF THE SMALLMOUTH BASS HATCHED IN THE DECADE OF 1940 IN MANITOULIN ISLAND WATERS

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Abstract

Yields of smallmouth bass (*Micropterus dolomieui*) hatched in the years 1941 through 1949 have been estimated for South Bay, Lake Huron. Subsidiary estimates for bass in neighboring waters were also made. Fluctuations in year-class strength appear to be more or less synchronous throughout the district. Variations in yield from the year classes in South Bay correlated directly with the algebraic sum of the monthly deviations from the mean air temperatures over the months July through October of the year of hatching.

Introduction

The intensive census of the sport fishery of South Bay maintained by the South Bay Fisheries Laboratory on Manitoulin Island in Lake Huron, together with lesser collections of data from a number of adjacent waters, permits comparison of the yields of hatches of the smallmouth bass, *Micropterus dolomieui* Lacépède, produced over the years 1941 through 1949. Much of this material has been analyzed by Fraser (1955). We have extended the analysis to 1954 for South Bay and have analyzed in addition the data accumulated for various neighboring waters.

The waters concerned in this report are, in the order of the extent of data obtained from them: South Bay, an enclosed bay of Lake Huron of approximately 30 square miles, on which an intensive creel census has been carried on since 1947; Lake Manitou, a lake of about 40 square miles which was censused intensively from 1947 to 1951; Big Bay, an open bay to the west of the entrance to South Bay with an area of 1 or 2 square miles from which records were available from 1947 to 1953; Thomas Bay, a much more enclosed bay of a size similar to that of Big Bay to the east of the entrance of South Bay, censused from 1948 to 1954; Whiskey Harbor, an area of Georgian Bay off the northeastern extremity of Manitoulin Island; Windfall Lake, a small inland lake with an area of about 1.6 square miles near Manitou Lake, for which samples were available for the years 1949 to 1951. These various waters are shown in Figure 1.

Manitoulin Island lies in the northern section of Lake Huron extending from 81° 30′ W to 83° 15′ W. and from 45° 30′ N to 46° 00′ N. Its southern shore forms part of the northern boundary of Lake Huron proper. The waters to the north and east of Manitoulin Island are, respectively, the North Channel and Georgian Bay.

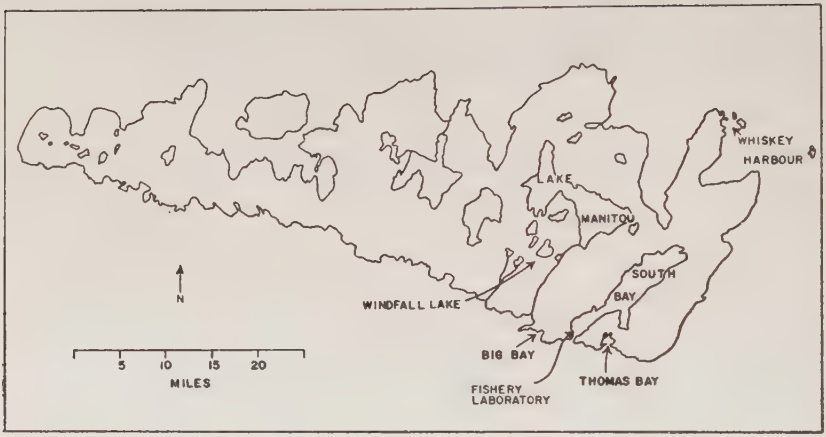

FIGURE 1.—Map of Manitoulin Island showing location of waters censused.

This report is based on the estimation of the age composition of the catch from scale samples. Fraser's (1955) readings were accepted for the period he covered. The remainder of the scales have been read by Miss N. Mudryk, D. Cucin, or the senior author. All these workers agree essentially in their assessments of age. The total number of scale readings employed for the populations outside South Bay can be seen by reference to Table 1.

ACKNOWLEDGMENTS

We are greatly indebted to the anglers and the lodge owners for their pleasant and long-continued cooperation in our creel census. We are also indebted to the other members of the laboratory staff who have gathered and recorded the data. In addition to those persons mentioned by Fraser (1955), we should like to acknowledge the work of Messrs. D. C. Mallory, D. J. Cavin, G. E. Finley, and J. M. Fraser. We are indebted to Mr. J. C. Kennedy for processing the data on punched-card computing equipment.

RATE OF GROWTH [1]

The age-length relations for the populations studied show some variations in growth rate (Table 1). The smallmouth bass in this region usually enter the fishery at ages IV or V and pass through it by age XII. Whiskey Harbor fish which grow at the slowest rate, do not enter the fishery until age V. Big Bay fish also grow relatively slowly. The Big Bay and the Thomas Bay populations can be distinguished by their growth rate and apparently do not intermingle to any significant degree even though these localities are only 6 miles apart. Nor does either of these two

[1] The results presented in this paper are based on the analysis of data which may be examined in the manuscript under the same title in the Ontario Fisheries Research Laboratory Library, University of Toronto.

populations appear to receive any significant number of recruits from South Bay although it lies between them. Several thousand smallmouth bass have now been marked in South Bay but only one or two of these have been reported as being captured in the bays outside.

TABLE 1.—*Age-length relationship up to age group X of various populations of smallmouth bass in catches taken by angling*

[Data for South Bay taken from Fraser (1955). The length given is fork length; to convert to total length multiply by 1.05. The minimum legal length over the period covered was 10 inches, fork length, 1947 through 1953 and 11 inches, total length, in 1954. Fraser's data include fish caught in nets. The number in parentheses is the number of scale samples examined. The age given is the number of completed annuli; the date of completion of the annulus was taken as July 1, the beginning of the bass season]

Age group	Whiskey Harbor	Big Bay	Thomas Bay	South Bay	Lake Manitou	Windfall Lake
III	....	10.0 (11)	10.6 (21)	9.2 (482)	10.0 (61)	10.2 (19)
IV	....	11.0 (92)	11.5 (66)	10.4 (562)	11.0 (179)	11.0 (37)
V	11.1 (53)	11.3 (209)	12.0 (81)	11.6 (479)	11.9 (108)	11.3 (26)
VI	11.8 (60)	12.1 (104)	12.8 (44)	12.8 (436)	13.4 (56)	13.5 (11)
VII	12.2 (60)	13.3 (28)	13.4 (16)	13.9 (296)	14.6 (38)	13.8 (12)
VIII	12.6 (29)	14.0 (13)	14.9 (8)	14.6 (138)	15.5 (27)	15.6 (7)
IX	13.7 (9)	14.7 (6)	16.0 (2)	15.7 (46)	16.4 (11)	16.5 (3)
X	13.5 (5)	16.5 (2)	16.0 (2)	15.9 (18)	16.5 (5)	17.5 (2)

YEAR-CLASS STRENGTH

In this report the estimates of year-class strength are of three types. The first and best is the estimate of the total contribution of the year class to the fishery as it passes through. This estimate, which can be made only if the total catch is known, has been termed the *virtual population* (Fry, 1949). It is derived by adding the contributions a year class makes to the fishery at each age. Complete coverage of the fishery was obtained only for South Bay. The virtual populations estimated for South Bay are shown in Table 2, which is an extension of Table XVI of Fraser (1955).

For Lake Manitou, Thomas Bay, and Big Bay the index of year-class strength has been the *total recorded catch*. For these waters the coverage has been considerable but we have no means of estimating what fraction of the total fishing effort was covered. It is believed, however, that the coverage was more or less equivalent from year to year so that a nearly

constant although unknown fraction of the catch was recorded. These estimates are derived from the catch data in exactly the same manner as is the virtual population; the yield of the year class is taken as equivalent to the number of samples accumulated from it as it passed through the fishery, but the figures are relative measures comparable only among themselves.

In the remaining two waters, Windfall Lake and Whiskey Harbor, the series of fish examined at the South Bay laboratory by no means represented a significant or consistent proportion of the catch. The age data

TABLE 2.—*The virtual population of smallmouth bass of various year classes in South Bay at different ages*

[Italicized figures are column means. These have been added to the respective year classes which have not yet completed their passage through the fishery to provide estimates of the yield still to come from them]

Year class	Age group									
	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1937	.....	.....	.....	...	...	...	...	5	5	5
1938	.....	.....	.....	...	...	...	43	16	0	0
1939	.....	.....	.....	...	...	111	29	13	3	0
1940	.....	.....	.....	...	212	76	14	4	4	4
1941	.....	.....	.....	846	383	119	16	4	4	0
1942	.....	.....	1,126	690	239	75	27	11	0	0
1943	.....	1,148	930	432	165	44	28	2	2	*2*
1944	641	636	418	233	64	32	6	4	*4*	...
1945	344	313	231	98	34	19	12	*8*	...	...
1946	903	698	383	190	112	42	*22*	...	...	...
1947	3,950	3,539	2,399	867	209	*65*	...	...	...	...
1948	2,447	2,367	1,778	684	*177*	...	...	...	...	...
1949	1,915	1,908	1,489	*505*	...	...	...	...	...	...

can be taken only to represent the age composition of the catch within the year of capture, for the number of fish examined bears no relation to the size of the annual take. These data therefore can be combined only on a relative basis. The representation of each age group in the sample for a given year was first found. Thus, in 1949 the sample from Windfall Lake contained (together with other ages), 15 percent age IV and 15 percent age V specimens. Over the 3 years of sampling, fish of these respective ages represented on the average 28 percent and 17 percent of the samples. To make fluctuations in the contributions comparable at the various ages, these two means, together with similar means found for the average representation of other age groups, were adjusted to an arbitrary common level. The level was so chosen that the resulting numbers were fractions and would not be confused with the data quoted as actual or estimated numbers caught. In the example the value for age IV in 1949 becomes 0.54 with this treatment and that for age V in the same year, 0.89. For age V in the sample taken in 1950 the adjusted value found for the strength of representation in the sample was 0.39. The mean representation of the strength of the 1945 year class, based on the samples taken at age IV in 1949, and at age V in 1950 is therefore (0.54 plus 0.39)/2 or 0.47. Such

means were extended as far as possible by compiling the values found over several ages. To illustrate the extent to which such ratios can be expected to reflect fluctuations in yield, ratios of this type over ages IV through VII were calculated for the South Bay data as well. These figures are included in Table 3 beside the estimated yield. The ratios do not fluctuate as widely as do the yields nor do they always put the year classes exactly in their proper order although the general agreement is good. These values for Windfall Lake and Whiskey Harbor cannot be considered as very dependable statistics and are offered in Table 3 only as subsidiary data.

TABLE 3.—*Estimates of year-class strength for smallmouth bass of South Bay, Lake Manitou, Big Bay, Thomas Bay, Windfall Lake, and Whiskey Harbor*

[For derivation of the respective columns, see text. The data for all localities but South Bay have been smoothed to two significant figures. Yields for the year classes of 1941 through 1943 in South Bay are estimates obtained by extrapolating the data given in Table 2]

Year class	South Bay		Lake Manitou (recorded catch)	Big Bay (recorded catch)	Thomas Bay (recorded catch)	Whiskey Harbor (relative contributions of ages V through VIII)	Windfall Lake (relative contributions of ages IV through VIII)
	Estimated total yield	Relative contributions of ages IV through VII					
1941.....	1,750	....	.....	...	...	...	...
1942.....	1,500	1.43	.....	...	...	...	...
1943.....	1,200	1.01	900	...	...	...	1.3
1944.....	641	0.50	1,100	66	90	0.86	0.9
1945.....	344	0.24	720	118	88	0.89	0.3
1946.....	903	0.48	640	150	67	1.1	1.3
1947.....	3,950	1.78	4,900	253	110	1.6	1.5
1948.....	2,447	1.25	.....	...	...	...	...
1949.....	1,915	....	...	...	...	...	...

As Fraser (1955) has already pointed out, the year class hatched in 1947 was outstandingly successful throughout the district. Production in the years 1944 through 1946 was in general lower. The data do not permit comparison of all six fisheries beyond this point but as far as they go they suggest that some meteorological factor may operate to influence the success of reproduction of smallmouth bass in the general region, as indeed Doan [2] has already suggested for Algonquin Park, Ontario. Accordingly, fluctuations in the year classes in South Bay and Lake Manitou were compared with deviations in the monthly mean temperatures from the long-term average (Table 4) taken from the Monthly Weather Maps. Support for the belief that such general deviations of air temperature might have a relation to local hydrographic conditions is presented in Figure 2 which shows thermal conditions in the surface waters of South Bay measured at the Laboratory dock (see Fig. 1) and expressed as thermal sums as they are related to deviations in the monthly mean air temperatures given in Table 4. The correlation between the thermal sums in the surface water

2Doan, K. H. The small-mouthed bass of Opeongo Lake, Algonquin Park Ontario. Ms report, Ontario Fish. Res. Lab. Univ. Toronto, 8 pp.

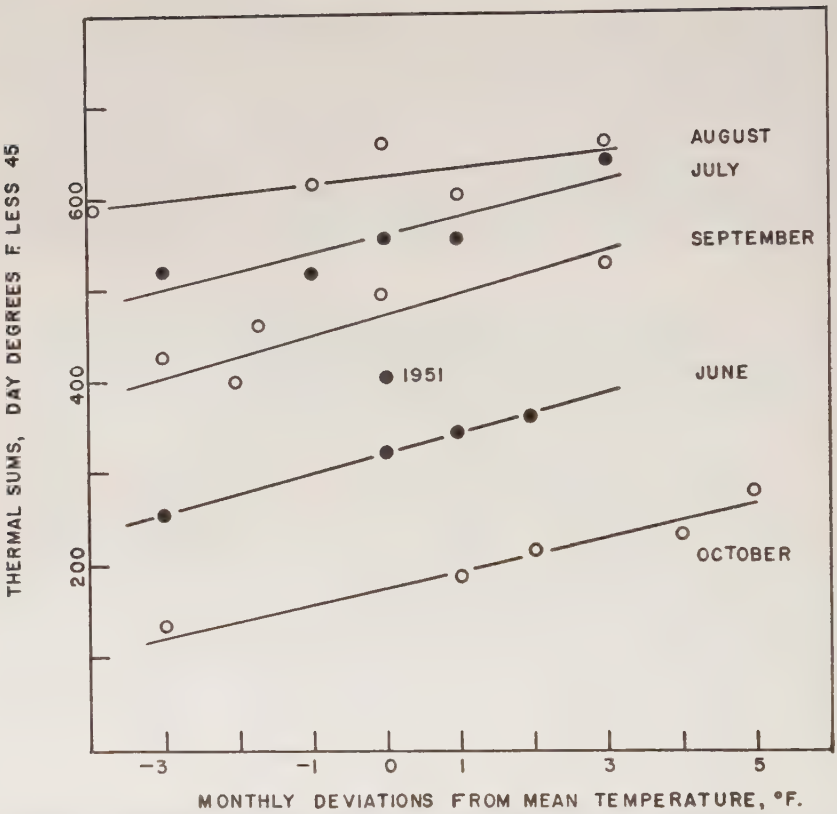

FIGURE 2.—Relation between deviation of monthly mean air temperature (F°) from the long-term mean and the summed heat experience in day-degrees in surface water of South Bay. Physiological zero for growth of the bass is taken arbitrarily as 45°F.

and the deviations of the regional air temperature from the long-term mean appears good except perhaps for August, the period of the highest water temperature where the trend through the data available is probably not reliable. Otherwise only one point, that for June 1951 is particularly aberrant. This June observation followed the warmest May recorded in Table 4.

The best correlation between the general regional air temperature and year-class production appears to be for the summed deviations over what can be presumed to be the growing season of the first-year fish, the months July to October inclusive. The sums of the deviations over these months (last column of Table 4) are plotted against the production of the year classes estimated for South Bay and Lake Manitou in Figure 3. The

TABLE 4.—*Monthly deviations from the long-term mean air temperature (F.°) in the region of Manitoulin Island as read from the monthly weather maps of Canada*

[The July-October column is the algebraic sum of the deviations]

Year	May	June	July	August	September	October	July-October
1941.....	2	4	1	−1	2	3	5
1942.....	2	1	0	0	0	2	2
1943.....	0	2	0	1	−2	1	0
1944.....	4	2	0	2	0	1	3
1945.....	−2	0	−2	2	0	−1	−1
1946.....	−2	−1	0	−2	0	6	4
1947.....	−5	0	1	7	3	9	20
1948.....	0	0	2	4	5	1	12
1949.....	2	5	3	3	−2	5	9
1950.....	0	−3	−3	−4	−3	4	−6
1951.....	5	0	−1	−2	−2	2	−3
1952.....	0	0	3	0	3	−3	3
1953.....	1	1	0	3	0	5	8
1954.....	−3	2	1	1	−2	1	1
1955.....	4	...	...	...	...	...	....

strength of the trend in Figure 3 suggests that annual variations in the water temperature during the first season of life has a major influence on the strength of the resulting year class.

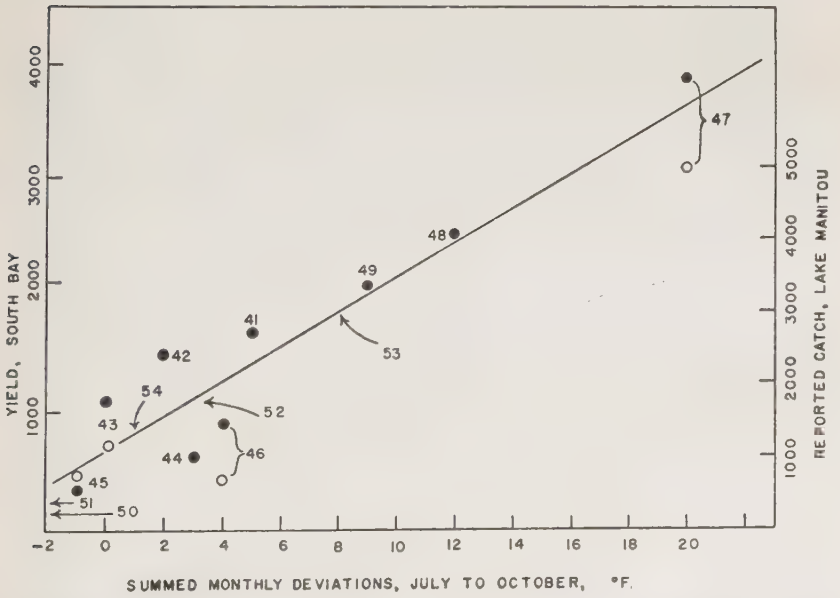

FIGURE 3.—Relation between the algebraic sums of the deviations of monthly mean air temperatures from July through October to the production of smallmouth bass. Open circles Lake Manitou, closed circles South Bay.

Outlook for the Smallmouth Bass Fishery in South Bay

The surprising goodness of fit of the trend line in Figure 3 is probably favored by a number of circumstances. In this region the smallmouth bass is almost at the northern limit of its range and even major increases in water temperature over the long-term mean probably do not bring conditions above its thermal optimum although we do not know what this optimum is. Thus the very exceptional season of 1947 probably led only to an exceptional year for growth, whereas toward the southern limit such an exceptionally warm year might actually suppress growth. Secondly, the two bodies of water for which the most data are available may be of approximately the right size to reflect this phenomenon well in this region. Big Bay and Thomas Bay, for which the samples, although small, are probably equally as representative of their respective populations as are those from South Bay and Lake Manitou do not show nearly as great dominance of the 1947 year class. Big Bay, open as it is to Lake Huron may well have temperature conditions that vary less from year to year than fluctuations in the regional air temperature would indicate, for Lake Huron is a vast reservoir for heat. Thomas Bay, on the other hand, has local conditions, brought about by its position and enclosed nature, that appear to make it consistently warmer than neighboring localities. This fact is indicated by the population of largemouth bass (*Micropterus salmoides*) which maintains itself there—a population which is unique in the locality.

The relations of variatons in year-class strength to variations in the monthly mean temperature reported by other authors are not as simple as has been found for the production of the decades of 1940 in South Bay, although they probably do lend some general support to the belief that survival is linked to water temperature. As documentation for this statement the temperature data for the waters covered in three other papers are presented in Table 5. Tester (1932) reported a dominance of the 1928 year class in Perch Lake, a small lake just south of Lake Nipissing at its eastern end. The season of open water in 1928 in that region was not markedly warmer than that of adjacent years except in July and August. Doan's manuscript (see Footnote 2) reports dominance of the 1933 year class in two Algonquin Park lakes; again the exceptional year-class strength was not associated with high July-October temperatures but the spring temperatures were warmer in that year than in the preceding and succeeding ones. In both cases there is some suggestion that a warmer-than-average year favors the production of smallmouth bass. The data of Stone, Pasko, and Roecker (1954) show a dominance of the 1938 and 1939 year classes in eastern Lake Ontario, and also relatively high summer temperatures in the same year.

The goodness of fit of the data for South Bay in Figure 3 seems to warrant a prediction, at least in general terms, of the course that the fishery will take, for the next few years. The presumptive strengths of the hatches of the years 1950 through 1954 are indicated by arrows on Figure 3. The summers of 1950 and 1951 were exceptionally cool and rather small year classes can be expected from these seasons. Smallmouth bass resulting from

TABLE 5.—*Monthly deviations from the long-term mean air temperatures (F.°) in the regions of Lake Nipissing, Algonquin Park, and Eastern Lake Ontario as read from the monthly weather maps of Canada*

[The July-October column is the algebraic sum of the deviations]

Locality and year	May	June	July	August	September	October	July-October
Lake Nipissing							
1927	−2	−4	−2	−5	2	3	−2
1928	−3	−4	0	2	−6	2	−2
1929	−4	−4	−4	−2	2	−2	−6
Algonquin Park							
1932	0	1	−3	2	0	3	2
1933	3	4	3	0	2	−2	3
1934	0	2	0	−4	3	−2	−3
Eastern Lake Ontario							
1937	1	1	1	4	−1	−1	3
1938	0	2	1	4	−2	2	5
1939	2	0	0	4	0	0	4
1940	1	−2	−1	1	−2	−4	−6
1941	2	2	2	−2	1	1	2
1942	3	2	−1	−1	1	2	1
1943	−1	2	1	−1	−2	−2	−4

those year classes can be expected to exert their major influence on the South Bay fishery in 1955 through 1957 with the major effect in the two later years when all influence of the three good years of 1947–1949 will have ended. This prediction is based on Fraser's (1955) finding that age-groups IV through VI make up approximately 70 percent of the catch. Subsequent fishing can be expected to improve slightly but on the basis of the year classes produced up to 1954 it cannot be expected to reach the excellence of the 1952 fishery which drew its major support from the large year classes of 1947 and 1948.

It is possible, however, that the intensive fishing of other species that has been carried out in South Bay since 1947 may have altered biotic conditions there in such a way as to change the relationship of year-class strength to temperature shown in Figure 3. This possibility does not seem to be great in view of the levels of the yields from the 1948 and 1949 year classes but it will be of interest to follow events in the next decade of hatching years to see whether the experimental fishery carried out on the other species affects the smallmouth bass.

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REPRODUCTION OF RESIDENT STRIPED BASS IN SANTEE-COOPER RESERVOIR, SOUTH CAROLINA

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Abstract

An unprecedented sport fishery for striped bass, *Roccus saxatilis* (Walbaum), has developed in the Santee-Cooper Reservoir within the past 10 years. From a creel census from September 1, 1954, to August 31, 1955, the annual harvest was conservatively estimated to exceed 64,000 striped bass; this species accounted for 6.7 percent of the total harvest (by number) of all game fish caught.

Exchanges between the reservoir population and those making seasonal runs in lower Cooper River is restricted to the navigation lock at Pinopolis Dam. Two methods were used during 1954 and 1955 to determine the extent of movement. Year-round fishing with a large trammel net indicated very limited use of the lock by striped bass. In 1954, a total of 606 striped bass were captured, tagged, and released in the Tailrace Canal below Pinopolis Dam. Out of 37 recaptures 33 were caught downstream, revealing a seasonal migratory trend, and only 4 had moved through the lock into the reservoir.

To determine sexual maturity of striped bass in the reservoir, 165 male and 243 female fish were examined between February 16, and June 1, 1955. Most of the males were ripe by the end of March. Changes in the ratio of gonad to body weight, were used to classify the stage of maturity of the females. A small percentage of the females were mature at 20 inches, total length. More than 88 percent of all females over 24 inches long had maturing, mature, or spent ovaries.

The principal spawning grounds in the reservoir were located in 1954 by the collection of eggs in large plankton nets. In 1955 a more intensive study revealed that the spawning period started during the first week of April and reached a peak between April 21 and May 5. The minimum temperature for spawning was 58° F.

Most of the striped bass in Santee-Cooper Reservoir are land-locked and apparently are able to complete a full life cycle in freshwater.

Introduction

Completed in 1942, the Santee-Cooper Hydroelectric and Navigation Project, diverted and impounded the Santee River. It now supports one of the most important sport fisheries for striped bass in the eastern United States. This situation is unique in that fishing is maintained on a year-round basis in a fresh-water reservoir from a stock largely perpetuated by the spawning of resident fish.

The reservoir system consists of two large, shallow lakes connected by a canal (Fig. 1). The combined area of the lakes is 160,500 acres when filled to the top elevation of 76 feet. The shore is flat; the shoreline totals 415

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miles. The main flow is derived from the Congaree and Wateree Rivers which drain from the Piedmont of South Carolina and North Carolina. The maximum depth of Lake Marion, the upper lake, is 36 feet and that of Lake Maultrie, the lower lake, is 66 feet; the mean depth of the reservoir is approximately 15 feet. Wilson Dam on Lake Marion blocks the original Santee River and diverts the flow through a 7-mile-long Diversion Canal into Lake Moultrie. The hydroelectric plant is located at Pinopolis Dam on Lake Moultrie. Water is discharged through the turbines into the 4-mile Tailrace Canal which continues via the Cooper River for a distance of 50 miles to the Atlantic Ocean. The lock at Pinopolis Dam permits navigation between the reservoir system and Cooper River and at times provides a possible means for the migration of fish.

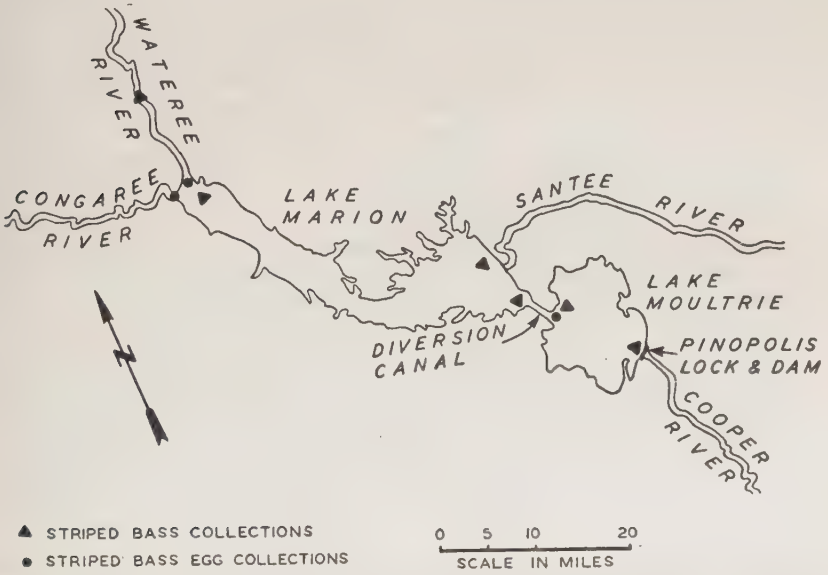

FIGURE 1.—Map of the Santee-Cooper Reservoir System including the location of striped bass and striped bass egg-collection stations.

Soon after the impoundment of the reservoir, seasonal concentrations of striped bass were observed in the Tailrace Canal below Pinopolis Dam. Catches were also reported by anglers from scattered localities in the reservoir. In the past 10 years the striped bass population has increased greatly in the reservoir.

The reservoir stock probably descended from the Santee River population which was trapped upstream at the time Wilson Dam was completed. Also, some recruitment has occurred by migration upstream through the lock from Cooper River.

The problem of determining whether the reservoir population is resident or migratory, concerns the operation of the lock at Pinopolis Dam which is the only means of passage to the reservoir available to migrating fish. Free movement of fish does not occur since the lock operations are irregular, depending on boat traffic. During the 5 years prior to July 31, 1954, the lock was operated by the South Carolina Public Service Authority, at the request of the South Carolina Wildlife Resources Department, to provide an opportunity for the seasonal migration of fish. From July 31, 1954, to September 1, 1955, the lock has been closed except for the infrequent passage of boats, and consequently the opportunity for fish migration has been greatly restricted.

On February 1, 1954, the South Carolina Wildlife Resources Department, supported partly by Federal Aid funds, inaugurated an investigation of the fish populations in the Santee-Cooper Reservoir; an important segment of the study concerned the life history of the striped bass.

Preliminary work by Scruggs and Fuller (1954), indicated that the migration of striped bass through the lock at Pinopolis Dam was not extensive and gave conclusive evidence that spawning occurred in the streams tributary to the reservoir. Scruggs (1955),[2] summarized the results of a full year's tagging designed to determine the migratory behavior of the Cooper River population and the degree of recruitment to the reservoir from this source. Raney and Woolcott (1955), reported in a racial study of southeastern striped bass that a significant difference occurred in the lateral-line scale count of those from the Reservoir as compared with samples from Cooper River, and concluded that two populations probably were present.

The present paper is concerned principally with the ability of striped bass to complete a full life cycle in the Reservoir. Also considered are the extent of migration through the Pinopolis Lock and the year-round availability and harvest by the sport fishery in the Reservoir. The status of sexual maturity of the Reservoir population was determined by an examination of the gonads of an adequate sample of adult fish. Actual spawning in the Reservoir was determined by the collection of fertilized eggs in large plankton nets.

Status of the Sport Fishery for Striped Bass

A creel census of the sport fishery, operated from five landings on Lakes Marion and Moultrie from September 1954 through August 1955, provided information on distribution, availability, and dominant size groups, as well as fishing effort. Commercial fishing is prohibited by law.

The creel census showed that 17,974 fishermen caught 95,750 fish represented by seven species. The catch of striped bass numbered 6,451, or 6.7 percent of the total catch. The average weight of 734 striped bass obtained

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2 Scruggs, George D. 1955. A study of the migration of the Cooper River population of striped bass. A paper presented at the annual meeting of the South Carolina Academy of Science. 11 pp. [Mimeographed]

from random samples in the fishery was 7.5 pounds. The catch of striped bass was significant during each month of the year, and was highest from October through January. The average catch of successful striped bass fishermen (Table 1) during this sample period did not vary widely from month to month.

The creel census is estimated roughly to have accounted for 10 percent of the total fishing effort for striped bass. The total annual harvest of striped bass from Santee-Cooper Reservoir was estimated to exceed 64,000 fish which weighed approximately 470,000 pounds.

TABLE 1.—*Results of a creel census on Lakes Marion and Moultrie from September 1, 1954, to August 31, 1955*

Successful striped bass fishermen		Striped bass catch		Successful striped bass fishermen		Striped bass catch	
Month	Number	Number caught	Catch per man	Month	Number	Number caught	Catch per man
September	106	118	1.1	March	326	372	1.1
October	366	793	2.4	April	395	542	1.4
November	667	1165	1.8	May	386	654	1.7
December	195	336	1.7	June	276	614	2.2
January	169	248	1.5	July	431	806	1.9
February	337	361	1.1	August	185	442	2.4

Migration Through the Lock at Pinopolis Dam

The lock at Pinopolis Dam has been used infrequently during the past several years as a navigation link between Cooper River and the Santee-Cooper Reservoir. The primary aim in opening the lock during the past 5 years has been to encourage interchange between the stocks of striped bass in Lake Moultrie and Cooper River, which was believed essential for the preservation of the striped bass fishery in the Reservoir.

The fish-way operations consisted of opening the lock 1 to 3 times per day to permit fish from the Tailrace Canal to be transferred to Lake Moultrie, or to pass from the lake to the canal. These operations were usually carried out from early January to the end of June each year. Beginning in 1954, two methods were employed to test the extent of the striped bass migration through the lock. In the first method a trammel net was fished periodically when the lock was operated. The second method consisted of tagging and releasing a large number of striped bass below Pinopolis Dam.

Trammel-net samples.—Starting on April 21, 1954, a large trammel net 65 feet long and 25 feet deep was suspended across the width of the concrete base of the upper lock gate to seal the entrance when the gate was opened into Lake Moultrie. The bottom and sides of the net were attached closely to the base and lock wall by metal snaps. The mesh size of the inner wall of the net was 2 inches, stretched measure.

The following procedure was carried out for each net sample taken:

(1) after the lower gate of the lock had been open for 1 hour the net was installed and the water level was raised to the level of Lake Moultrie; (2) the upper gate was then opened and the net was allowed to fish for 1 hour; (3) after the operation was completed the catch was sorted from both sides of the net to determine direction of movement.

In the period between April 21, 1954, and April 20, 1955, 29 sets of the net caught a total of 2,569 fish represented by 14 species. Only four small striped bass were captured. Herring (*Alosa mediocris* and *A. aestivalis*), channel catfish (*Ictaluras punctatus*), and billfish (*Tylosurus marinus*) were the only large species that showed a well-defined movement through the lock.

From April 21, to July 31, 1954, the lock was opened 179 times as follows: fish transfer, 140; boat passage, 29; and for trammel-net samples, 10. On July 31, 1954, lock operations for fish transfer were discontinued and until the end of the study period on April 20, 1955, trammel-net samples comprised 34 percent of all openings. In 1954 and 1955 the netting program started and ended on dates selected to include the height of the striped bass spawning season. Since the net caught very few striped bass over the period it would appear inconceivable that a large interchange occurred between the populations in Cooper River and the Reservoir.

Marking and recovery.—During the spring migration, March 25, to July 1, 1954, 545 striped bass were caught in dip and cast nets in the Tailrace Canal and tagged. An additional 61 were caught on hook and line and tagged between October 19 and December 16, 1954. The fish were marked with Peterson disk tags affixed by piercing the body with a nickel pin just below the first dorsal fin. All tagged fish were released in the Tailrace Canal below Pinopolis Dam. All tag recoveries were obtained by cooperation of sport fishermen. No reward was offered for tag returns but an effort was made to obtain them by placing announcements in newspapers and by posting printed notices at landings on the Reservoir and along Cooper River.

Of the 606 fish tagged and released, 37 (6 percent) were returned in the 18-months ending August 31, 1955. Thirty-three (89 percent) of the recaptures were returned from Cooper River and the Tailrace Canal; 4 tags (11 percent) were returned from Lake Moultrie. The latter fish moved upstream through the Pinopolis Lock. Figure 2 illustrates the distribution of tag recaptures by the month.

The movement of marked fish in Cooper River indicates that the population was located in the upper part of the river and Tailrace Canal during the spring, early summer, and late winter. The high percentage of returns from the upper 30 miles of the river (94.5 percent) suggests a population which has a predilection for fresh water and confirms the general observations of anglers and commercial fishermen that little or no coastal migration occurs in South Carolina. The most distant recoveries were of 2 fish taken 50 miles downstream at the mouth of Cooper River. The average time at liberty for the 33 tagged bass was 187 days. The longest time out was

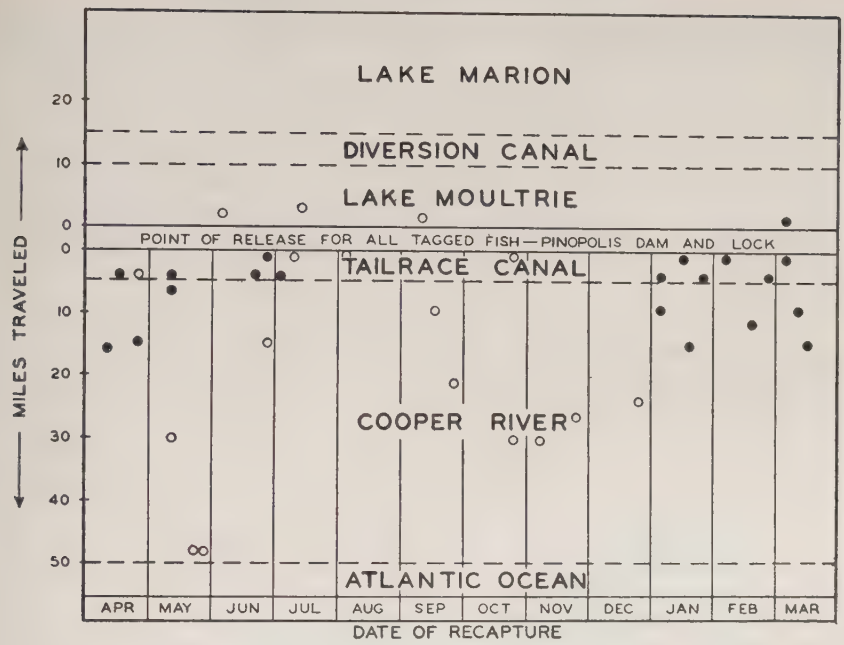

FIGURE 2.—Location and date of recapture of 37 striped bass in Cooper River and Lake Moultrie from April 1954 through August 1955. Open dots—recaptures in 1954; solid dots—recaptures in 1955.

430 days; this fish was captured near the original point of release in the Tailrace Canal. Nine other tags were out longer than 300 days.

Of the four tag returns from striped bass which moved through the lock into Lake Moultrie, three were caught within an average of 74 days. The other fish was free for 324 days. The movement of the four tagged bass in Lake Moultrie averaged a minimum of 1 mile. All were from groups tagged between April 13 and May 19, 1954; it seems possible that particular schools of fish passed through the lock between or soon after these dates. Two of the four caught were tagged on May 10, 1954. Of 197 tagged bass released after May 10, 1954 10 were later caught below Pinopolis Dam but none were taken in the Reservoir. The fishing pressure in all seasons was greater in the Reservoir than in Cooper River.

After routine operations for fish transfer were discontinued, the lock was opened only 55 times at irregular intervals between July 31, 1954, and July 31, 1955, to accommodate boat traffic. Since the average time required for each boat was 15 minutes, the lock was open to migrating fishes for only about 13 hours during the period from the end of the 1954 season to the end of the 1955 season. Evidence obtained from both the trammel-

net samples and tag recaptures indicates that there is little striped bass migration through the lock.

Sexual Maturity

In view of the evidence indicating that the stock of striped bass in the Reservoir was not added to appreciably by recruitment from that in Cooper River, it was concluded that the Reservoir population was composed mostly of resident stock. The question then arose as to whether the resident fish were able to mature sexually and reproduce successfully without having spent at least part of their life cycle in saline water.

State of gonads.—Prior to and during the spawning season of 1955, adult striped bass were collected at various locations in Lake Marion and Lake Moultrie (Fig. 1). The specimens were obtained principally from the sport fishery but were supplemented by a sizeable gill-net catch. Between February 16 and June 1, 1955, 408 large bass were examined, of which 243 were female and 165 were male. They were inspected for gonad development, weighed, and classified in accordance with the following categories:

Immature Females: The ovaries were small with no sign of developing ova. The color in fresh fish varied from pale grey to a deep red. The main blood vessels of the ovaries were not dilated. The rattio of gonad weight to body weight ranged from 1:70 to 1:300. Not expected to spawn this season.

Maturing females: The ovaries were enlarged and contained developing ova. Color ranged from cream to a greenish-yellow. The blood vessels of the ovaries were dilated. The ratio of gonad weight to body weight averaged 1:40. Expected to spawn this season.

Mature females: The ovaries were greatly enlarged, with developed ova. The color ranged from pale green to a darker shade of green as ripeness was approached. The blood vessels were extremely dilated. The ratio of gonad weight to body weight averaged around 1:10. These fish were almost ripe.

Spent females: The ovaries were flabby. A few large ova were occasionally present. When the fish was stripped a bloody discharge was extruded. The color was a light shade of purple. Spawning had been completed by these fish.

Males: The testes were classified as immature, maturing, or ripe. Immature testes were small and thread-like. Maturing testes were very large and white. Ripe tests were easily determined by the ready extrusion of milt when the fish were stripped.

The condition of the testes, determined by gross inspection, presented no difficulty in classification since practically all were either in the maturing or ripe stage at the time of examination. Soon after the study began in early spring it became apparent that the males were progressing from the maturing to the ripe stage as the season advanced. Gonads of approximately 98 percent of all males examined contained a bountiful supply of milt by the end of March. The smallest size at which the males matured was about 10 inches, total length.

Since practically all male fish were found to mature successfully, emphasis was placed on the study of sexual development of the females. As the spawning time approached the ovaries increased to a much larger size and consequently made up a higher percentage of the total fish weight. A similar change was previously noted by Vladykov and Wallace (1952) who gave comparative data on gross and gonad weight of striped bass in Chesa-

peake Bay. They examined a large sample of males but the number of females was rather small.

Among the 243 females examined, the total length ranged from 14 to 36.9 inches (Table 2). The relation between ovary development and length is clearly evident. As the season advanced the larger females were able to mature their ovaries. A small percentage of the females matured at about 20 inches but the majority did not mature until they reached 24 inches (Fig. 3). In order to show percentage maturity at different lengths all maturing, mature, and spent fish in each length group were considered as

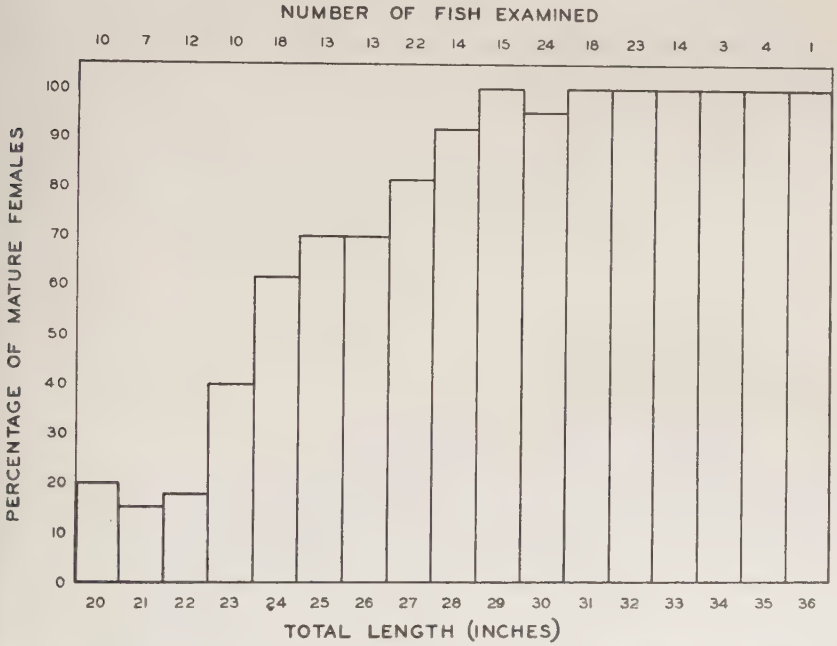

FIGURE 3.—Percentage of female striped bass able to mature sexually (includes all maturing, mature, and spent specimens) taken in Lakes Marion and Moultrie during February 16 to June 1, 1955.

a unit. A definite correlation is shown between the length of the fish and the percentage which were mature up to the 29-inch group. All fish less than 20 inches in total length were immature; from 20 to 24 inches, 23 percent were mature; from 24 to 29 inches, 75 percent were mature; and from 29 to 37 inches, over 99 percent were considered to be mature.

Spent striped bass of both sexes were consistently lighter in weight than fish of the same length (Table 3), particularly for the larger sizes. As expected, the weight loss for females was considerably greater than that for males.

TABLE 2.—*Number of immature, maturing, mature, and spent female striped bass taken from February 16 to June 1, 1955, in Lakes Marion and Moultrie*

[See text for descriptions of various states of organs]

Total length (inches)	All fish		Immature		Maturing		Mature		Spent	
	Number	Percentage of total	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
14-14.9	1	0.4	1	100.0	..	....	..	....	..	....
15-15.9	1	0.4	1	100.0	..	....	..	....	..	....
16-16.9	4	1.6	4	100.0	..	....	..	....	..	....
17-17.9	5	2.1	5	100.0	..	....	..	....	..	....
18-18.9	7	2.9	7	100.0	..	....	..	....	..	....
19-19.9	4	1.6	4	100.0	..	....	..	....	..	....
20-20.9	10	4.1	8	80.0	1	10.0	1	10.0	..	....
21-21.9	7	2.9	6	81.0	1	19.0	..	....	..	....
22-22.9	12	4.9	10	83.0	2	17.0	..	....	..	....
23-23.9	10	4.1	6	60.0	2	20.0	1	10.0	1	10.0
24-24.9	18	7.4	7	39.0	9	50.0	..	....	2	11.0
25-25.9	13	5.4	4	31.0	7	54.0	..	....	2	15.0
26-26.9	13	5.4	4	31.0	2	15.0	1	8.0	6	46.0
27-27.9	22	9.0	4	18.0	2	9.0	2	9.0	14	64.0
28-28.9	14	5.8	1	7.0	..	....	4	29.0	9	64.0
29-29.9	15	6.2	..	....	3	20.0	5	33.0	7	47.0
30-30.9	24	9.9	1	4.0	2	8.0	11	46.0	10	42.0
31-31.9	18	7.4	..	....	2	12.0	8	44.0	8	44.0
32-32.9	23	9.5	..	....	..	....	7	30.0	16	70.0
33-33.9	14	5.8	..	....	..	....	1	7.0	13	93.0
34-34.9	3	1.2	..	....	..	....	1	33.0	2	67.0
35-35.9	4	1.6	..	....	..	....	1	25.0	3	75.0
36-36.9	1	0.4	..	....	..	....	1	100.0	..	....
Totals	243	100.0	73	....	33	....	44	....	93	....

TABLE 3.—*Comparison of average weights of male and female striped bass from Lakes Marion and Moultrie from February 16 to June 1, 1955*

[Includes specimens taken before and after spawning]

Total length (inches)	Male				Female			
	Prespawning		Spent		Prespawning		Spent	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
10-10.9.....	3	0.5	..	....	2	0.5	..	....
14-14.9.....	..	....	..	....	1	1.8	..	....
15-15.9.....	3	1.8	..	....	1	2.0	..	....
16-16.9.....	2	2.5	1	2.2	4	2.5	..	....
17-17.9.....	6	2.7	..	....	5	2.6	..	....
18-18.9.....	5	3.2	..	....	7	3.1	..	....
19-19.9.....	26	3.6	..	....	4	3.2	..	....
20-20.9.....	33	4.1	..	....	10	3.9	..	....
21-21.9.....	25	4.8	1	4.2	7	4.8	..	....
22-22.9.....	10	5.4	2	4.4	12	5.5	..	....
23-23.9.....	5	5.9	..	....	12	6.0	1	5.3
24-24.9.....	6	7.0	4	5.9	17	6.8	2	5.8
25-25.9.....	6	7.2	6	6.1	18	7.0	2	6.0
26-26.9.....	1	7.5	4	6.8	11	7.7	6	6.2
27-27.9.....	3	8.9	8	8.0	13	8.6	14	7.6
28-28.9.....	2	9.9	2	8.4	3	10.5	9	8.8
29-29.9.....	2	10.5	3	9.8	12	11.5	8	10.0
30-30.9.....	..	....	1	11.9	10	13.5	10	11.1
31-31.9.....	..	....	..	....	12	14.5	8	12.0
32-32.9.....	..	....	..	....	6	16.0	16	13.6
33-33.9.....	..	....	..	....	4	17.0	13	14.9
34-34.9.....	..	....	..	....	1	19.0	2	16.5
35-35.9.....	..	....	..	....	1	22.0	3	18.0
36-36.9.....	..	....	..	....	1	24.5	..	....
Totals.....	138	....	32	....	174	....	94	....

A progressive change in the condition of the female gonads was observed as the spawning season advanced (Table 4). In the preparation of the table only fish between 24 and 36.9 inches long were considered since these fish constituted 75 percent of the total number examined and the majority of the fish that were able to mature fully. The total collection was composed of females covering a wide range in length; the predominance of certain sizes at various times may account for shifts in the percentages, especially for the immature fish. It is possible also that fish earlier classed as immature may have matured as the season advanced.

Sex Ratio.—The sex ratio varied during the collecting periods but the change reflects sampling bias rather than an actual shift of the ratio in nature. Of 162 fish examined prior to March 31, 74.8 percent were males and 25.2 percent were females. The collection of 139 fish made during April was composed of only 4.4 percent males and 95.6 percent females. During May a collection of 107 bass included 35.5 percent males and 64.5 percent females. Of the total 408 striped bass, 40 percent were males and 60 percent were females. The fluctuation in the sex ratio may be explained by the greater activities of males prior to the spawning season. After spawning began, the males were concentrated on the spawning grounds, whereas the females lingered below these areas and gradually moved up

TABLE 4.—*Percentage of immature, maturing, mature, and spent female striped bass from Lakes Marion and Moultrie, arranged by time periods in 1955*

[All specimens over 24 inches in total length]

Date of collection	Number examined	Percentage immature	Percentage maturing	Percentage mature	Percentage spent
February 16 — March 31	21	23.8	47.6	28.6	0.0
April 1 — April 15	35	17.2	22.8	48.6	11.0
April 16 — April 30	78	7.7	21.8	14.1	56.4
May 1 — May 31	48	4.2	2.1	2.1	91.6

as they matured. A majority of the bass were taken below the spawning grounds.

Growth and age at maturity.—Scale samples were collected from striped bass for age and growth determination in both 1954 and 1955. The scales were read and measured under magnification. Lengths were calculated by direct proportion.

The growth in length was greatest during the first 3 years of life (Table 5). The average growth increment was greater between the first and second years. The overlapping in the length ranges was considerable due to some extent perhaps, because of a rather long spawning season and a faster growing tendency of certain individuals.

The smallest mature male examined was 10.1 inches long and only 1 year old. The majority of the males did not mature until their second year. The largest male examined was 30 inches long and in its seventh year.

Approximately 23 percent of the females were mature by their fourth year. Maturity was 65 percent at 5 years, and 85 percent by the sixth year. Practically all females beyond the sixth year were mature. The largest female examined was 36 inches long and was in its tenth year.

The length distribution of 726 bass caught in the sport fishery (Fig. 4) implies a major support from age-groups III–IX. Although age-groups I and II are represented, the smaller number caught was probably due to selective fishing for the larger sizes.

TABLE 5—*Total length (inches) of the age groups at capture and calculated growth (from scale measurements) of striped bass in Santee-Cooper Reservoir*

[Fish collected in 1954 and 1955]

Age group	Number of fish	Length at capture		Year of life	Calculated length	Increment
		Average	Range			
I	108	7.8	5.2–11.4	1	7.1	...
II	92	15.1	12.4–17.8	2	14.9	7.8
III	70	20.3	16.3–22.5	3	19.5	4.6
IV	56	24.1	20.1–25.3	4	22.2	2.7
V	30	26.0	23.3–27.1	5	25.1	2.9
VI	31	27.8	25.2–29.1	6	27.5	2.4
VII	15	30.5	28.7–31.5	7	30.1	2.6
VIII	9	32.8	31.6–33.5	8	32.3	2.2
IX	3	35.2	34.1–36.	9	34.6	2.3

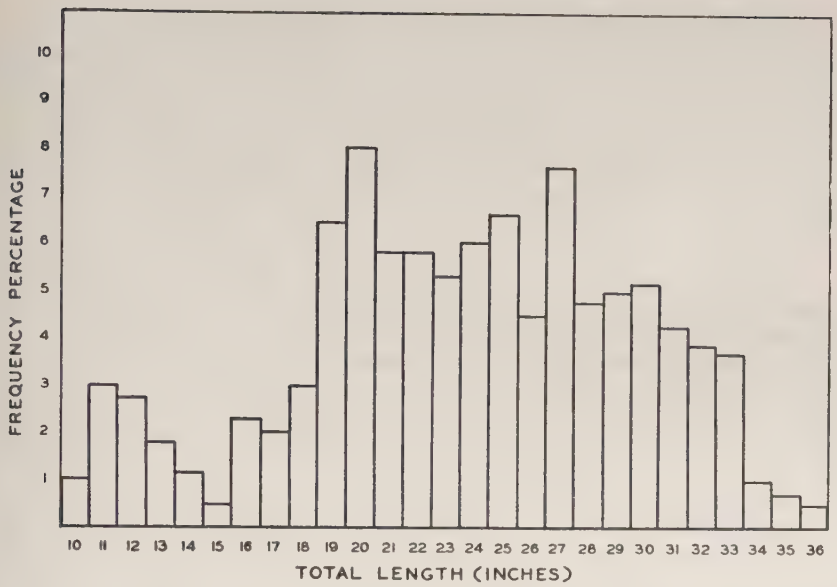

FIGURE 4.—Length distribution of 726 striped bass caught in the Santee-Cooper Reservoir from September 1, 1954 to August 1, 1955.

The strength of older age-groups indicates high availability of mature-size fish as brood stock.

SPAWNING

During the spring of 1954 a survey was made to locate the spawning grounds of the striped bass in the Santee-Cooper System. This work was intended mainly as exploratory to find direct evidence of spawning. Elsewhere, Tresselt (1952) made a thorough study of striped bass spawning grounds of some Virginia streams tributary to Chesapeake Bay through the collection of eggs in plankton nets. Calhoun and Woodhull (1948) summarized their studies in locating striped bass eggs and larvae in the Sacramento and San Joaquin Rivers, California.

The preliminary study in 1954 was successful in that eggs and larvae of the striped bass were taken in the Congaree and Wateree Rivers, tributary streams of the Reservoir, in the Diversion Canal, and also downstream in Cooper River. A plankton net, 1 meter in diameter, made of nylon netting was towed by boat to collect samples. The sampling was carried out more intensively in Cooper River where it was found that spawning occurred between April 22 and May 11 in the upper 12 miles of the river.

Further study was intended to delimit the spawning season of 1955 and to determine the relative intensity of spawning in various localities in the

Reservoir area. Only a few collections were made in Cooper River. Again 1-meter plankton nets were used but they were anchored in the current in the Congaree and Wateree Rivers, and in the Diversion Canal.The samples were taken periodically for the duration of the spawning season, by setting the net from 30 minutes to 1 hour at each station on selected dates. All samples were obtained from surface sets since collections in 1954 revealed more eggs at the surface than at the bottom. Samples were preserved in formalin.

Diversion Canal.—Samples were taken near the mouth of the canal between March 22 and June 1, 1955. The erratic flow during the spawning season ranged from 1 mile to about 4 miles per hour. The rate of flow was determined by the discharge of water from tributary rivers into Lake Marion and the amount drawn through and discharged by the hydroelectric plant at Pinopolis Dam. The maximum depth of the canal at the sampling station was 30 feet; the bottom is composed of marl. Eggs were first collected on April 6, when the water temperature was 58°F. (Table 6).

TABLE 6.—*Collection of striped bass eggs from the Diversion Canal in 1955*

Date	Current	Water temperature (F.°)	Number of samples	Sample period (minutes)	Number of eggs	Number per minute
March 22	Medium	57	1	45	0	0.00
March 23	Medium	57	1	30	0	0.00
April 6	Fast	58	1	60	5	0.08
April 21	Fast	71	1	60	3	0.05
April 27	Very Fast	71	1	60	55	0.92
May 3	Medium	70	1	60	0	0.00
May 11	Slow	74	1	60	41	0.68
May 18	Slow	72	1	60	0	0.00
May 25	Slow	74	1	60	0	0.00
June 1	Slow	76	1	30	0	0.00

Other egg collections were made on April 21, April 27, and on May 11. The spawning may have reached a peak on April 27. Spawning in the canal is believed to have been maintained by intermittent runs of fish from Lake Moultrie.

Congaree River.—Collections were made between March 25 and June 9, 1955 below the bridge on U. S. Highway 601, approximately 2 miles from the mouth of the river. The Congaree is very turbid from an abundance of red clay. The flow is maintained by the discharge from Saluda Dam on Lake Murray, 50 miles upstream and by the considerable flow from Broad River. The estimated volume of flow during the spawning season ranged from 2,200 to 39,100 cubic feet per second. Eggs were first collected on April 8, when the water temperature was 61°F. and other collections were made on April 21, May, 5, May 19, and June 2 (Table 7). Spawning apparently reached a peak on April 21.

The collection of eggs suggests that the Congaree was the most important spawning ground sampled. The length of the season and number

of eggs collected were greater than from any other area. Since eggs were in various stages of development, spawning probably took place over a long stretch of the river.

Wateree River.—The Wateree River was sampled between March 25 and June 9 at a station 200 yards upstream from its confluence with the Congaree River. The Wateree is much clearer than the Congaree although the presence of considerable organic matter and debris made th sorting difficult in all samples. The flow is primarily dependent on the discharge

TABLE 7.—*Collection of striped bass eggs from the Congaree River in 1955*

Date	Current	Water temperature (F.°)	Number of samples	Sample period (minutes)	Number of eggs	Number per minute
March 25	Medium	59	1	60	0	0.00
April 8	Fast	61	1	60	65	1.08
April 21	Very Fast	70	1	30	2500	83.40
May 5	Slow	74	1	30	155	5.17
May 12	Slow	72	1	30	0	0.00
May 19	Fast	70	1	30	69	2.30
May 26	Very Fast	74	1	45	0	0.00
June 2	Fast	76	1	30	6	0.20
June 9	Fast	77	1	30	0	0.00

from Wateree Dam, located approximately 60 miles from the mouth; during the spawning season it ranged from 1,480 to 44,885 cubic feet per second. The first eggs were collected on April 8, when the water temperature was 59°F. and others were collected on April 21, May 5, and May 19 (Table 8). Spawning may have reached a peak on May 5.

Spawning in the Wateree and Congaree Rivers was maintained by runs from Lake Marion.

The combined collection of eggs from the three spawning areas in the Reservoir, indicate that the minimum duration of spawning extended from April 6 to June 2, 1955 for a total of 58 days—and that spawning reached a maximum intensity in the latter part of April.

Cooper River.—Collections of eggs in 1954 proved that spawning took place during April and May in the upper 12 miles of the river. Samples were taken in 1955 between March 12 and April 1, but collecting was discontinued after April 1, because of time limitations and shortage of personnel. The station was approximately 17 miles below the Pinopolis Dam. Eggs were first collected on March 16, when the water temperature reached 61° F. Eggs were also collected on March 17, 19, 21, and 26. Although no eggs were obtained on April 1, this failure does not prove that spawning was completed since the water temperature had been greatly lowered at this time by unseasonal cold.

The significance of the spawning ground below Pinopolis Dam lies in the fact that it is distantly separated from spawning areas in the Reservoir; it is not necessary for bass from Cooper River to pass through the

lock to find a satisfactory spawning area. Spawning began several weeks earlier in Cooper River, possibly because of a higher water temperature and early sexual maturity of the fish.

Volume of spawning.—Difficulties inherent in the sampling technique prevented any attempt to obtain detailed quantitative estimates of the volume of eggs discharged into the Reservoir. Such factors as erratic current velocities, variation in vertical distribution of eggs, and the infrequent sampling made such estimates impractical. A very rough index is provided by the number of eggs collected per minute on certain dates.

TABLE 8.—*Collection of striped bass eggs from the Wateree River in 1955*

Date	Current	Water temperature (F.°)	Number of samples	Sample period (minutes)	Number of eggs	Number per minute
March 25	Fast	58	1	30	0	0.00
April 8	Very Fast	59	1	60	11	0.18
April 21	Very Fast	67	1	45	9	0.20
May 5	Very Fast	70	1	30	106	3.53
May 12	Fast	73	1	45	0	0.00
May 19	Fast	72	1	30	3	0.10
May 26	Very Fast	74	1	30	0	0.00
June 2	Very Fast	76	1	30	0	0.00
June 9	Fast	76	1	30	0	0.00

Between April 1 and April 15, the percentage of females in the Reservoir, that were mature or almost ripe reached a peak (Table 4). Spawning began on April 6 and reached a peak between April 21 and May 19. As the spawning continued the percentage of fish in the mature stage declined steadily; in sharp contrast, the number of spent fish rose continuously. By the end of May, when spawning was near completion, as judged from egg collections, the percentage of spent fish reached 91.6 percent of the total.

ABUNDANCE OF YOUNG

Efforts to collect young striped bass, made soon after the spawning seasons, were successful in both 1954 and 1955. A total of 281 young of the 1954 year class were collected by seines from widely scattered areas along the shore of both lakes between June 23, 1954, and April 29, 1955. On June 30, 1955, 55 young were collected from Lake Moultrie and on July 29, 1955, 35 were caught in Lake Marion.

The relative ease with which young striped bass could be caught after the spawning seasons of 1954 and 1955 reflects wide distribution and relatively high abundance.

The collections of young-of-year gives final evidence that the life cycle of striped bass is completed in Santee-Cooper Reservoir.

Acknowledgments

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SIX YEARS OF CATCH STATISTICS ON YELLOWSTONE LAKE

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ABSTRACT

The U. S. Fish and Wildlife Service collected catch statistics on Yellowstone Lake and adjacent waters from 1950 to 1955 as part of an investigation on the status of the cutthroat trout fishery and the fish populations. Methods for estimating numbers of fishermen, hours of effort, and catch, were developed for each unit of the fishery and were used to compute estimates for all years of the 6–year period.

One feature of this fishery is the presence of only one species of sport fish in these waters. Another is an unusual hourly distribution of fishing throughout the day. Very little fishing is done before 7 a. m. and thereafter three peak periods of fishing effort occur, in the late morning, in the afternoon, and in the evening. Another characteristic is a remarkable uniformity of angling pressure among days of the week. The "resort" character of the Yellowstone situation explains these unusual tendencies. Good opportunity also is afforded in this fishery for studies on the effects of changes in regulations.

Distribution of fishing effort according to area and season has been very constant from year to year. The Fishing Bridge fishery peaks early in the year and declines rapidly. The West Thumb fishery is smaller, but is sustained throughout the season. The lake outlet area accounted for 30 percent of the total catch of Yellowstone Lake, and 27 percent of the combined lake and river catch. The components of the fishery contributed the following average annual catches: West Thumb Dock guides and rowboats, 25,450 fish, or 9.98 percent of the lake total; Fishing Bridge Dock guides and rowboats, 54,239 fish, or 21.27 percent; Lake Dock guides and rowboats, 33,387 fish, or 13.09 percent; lake shoreline, 65,271 fish, or 25.60 percent; Fishing Bridge 6,474 fish or 2.53 percent; private boats, 70,123 fish, or 27.50 percent. The average annual lake catch for the 6–year period was 254,944 fish. The average catch in the river was 33,575 or 13.16 percent of the lake catch.

Trends for the lake and river fishery as a whole show an increase in fishing effort up to 1952, followed by a small reduction in 1953 and increases in 1954 and 1955. Fishing effort varied with the numbers of tourists, although the reduction in fishing pressure from 1952 to 1953 was greater than the reduction in numbers of tourists. The successes of individual components of the fishery have fluctuated independently of each other from year to year. The catch per fisherman hour for river and lake combined in 1955 was 0.671 fish, compared with 0.510 in 1951, 0.519 in 1952, 0.508 in 1953, and 0.584 in 1954.

Reductions in mean lengths of the catch were evident up to 1952. The mean lengths were greater for 1953–1955 than those of 1952, a condition that is attributed to weak year classes.

The reduction of the limit from five to three fish in 1953 did little toward reducing total catch, but the shortened season had a decided effect on the reduction of the catch.

INTRODUCTION

The cutthroat trout (*Salmo clarki lewisi*) fishery on Yellowstone Lake and River in Yellowstone National Park, Wyoming, has been under investigation by the U. S. Fish and Wildlife Service for several years. The

postwar upsurge in the popularity of the fishery, with attendant apprehension that its stability might be threatened, was the occasion for intensifying the studies in 1950. The present program of investigation was organized in that year, with the cooperation of the U. S. National Park Service, which manages the Yellowstone lands and waters. The purpose of the study has been to determine the characteristics of the fish populations and of the fishery so that recommendations for maintaining the fish stock could be presented to the National Park Service for its consideration.

The creel census has been a primary feature of the investigation. The census of 1950 covered the fishery of Lake Yellowstone, and was succeeded the following year by an expanded and intensified census that included the 15 miles of Yellowstone River between Fishing Bridge and Canyon (Fig. 1). A report on the 1950 and 1951 census has been published (Moore, Cope, and Beckwith, 1952). Considerable detail concerning census methods, characteristics of the populations, the program, the fishery, and estimates of fishing effort, catch, and numbers of anglers were included. The mathematical basis for the census on the lake shoreline and the river was emphasized in the second part of the paper. Variance estimates for catch and effort were computed for the shoreline and river fisheries. A few of the estimates reported in the paper are included here but are slightly modified on the basis of later information.

The present paper, in addition to bringing together data collected during the 6-year period from 1950 to 1955, emphasizes the features of the fishery and the populations of Yellowstone Lake to bring out the significance of the study. The value of this effort lies not so much in the presentation of estimates of catch and effort as in the accentuation of the unique aspects of the fishing patterns in these waters. The creel census results are of course extremely important for the control of the fishery, but the occasion for this paper is the existence of unusual circumstances affecting the distribution of catch and the regulation of the fishery.

One of the important characteristics of the Yellowstone Lake fishery is the presence of only one species of sport fish. Two species of cyprinids and the longnose sucker (*Catostomus catostomus*) also occur in this drainage, but the Yellowstone cutthroat comprises virtually the entire catch. In terms of management of a resource this is a unique situation.

Another feature of the fishery is the "resort" character of the accommodations for tourists. This has apparently affected the hourly distribution of fishing effort, forming a fishing pattern different from those seen in most fisheries. A knowledge of the hourly distribution of fishing is often important in creel census programs where sampling is done for less than the entire fishing day.

Good opportunity is afforded at Yellowstone Lake for the study of the effects of changes in regulations. This is due in part to the excellent cooperation received from the National Park Service and the Yellowstone Park Company in the collection of data. Also, there was a good opportunity for rather complete creel census coverage due to the existence of good sampling locations on the lake and river and to the good control of tourists at park gates, on roads, and on the lake.

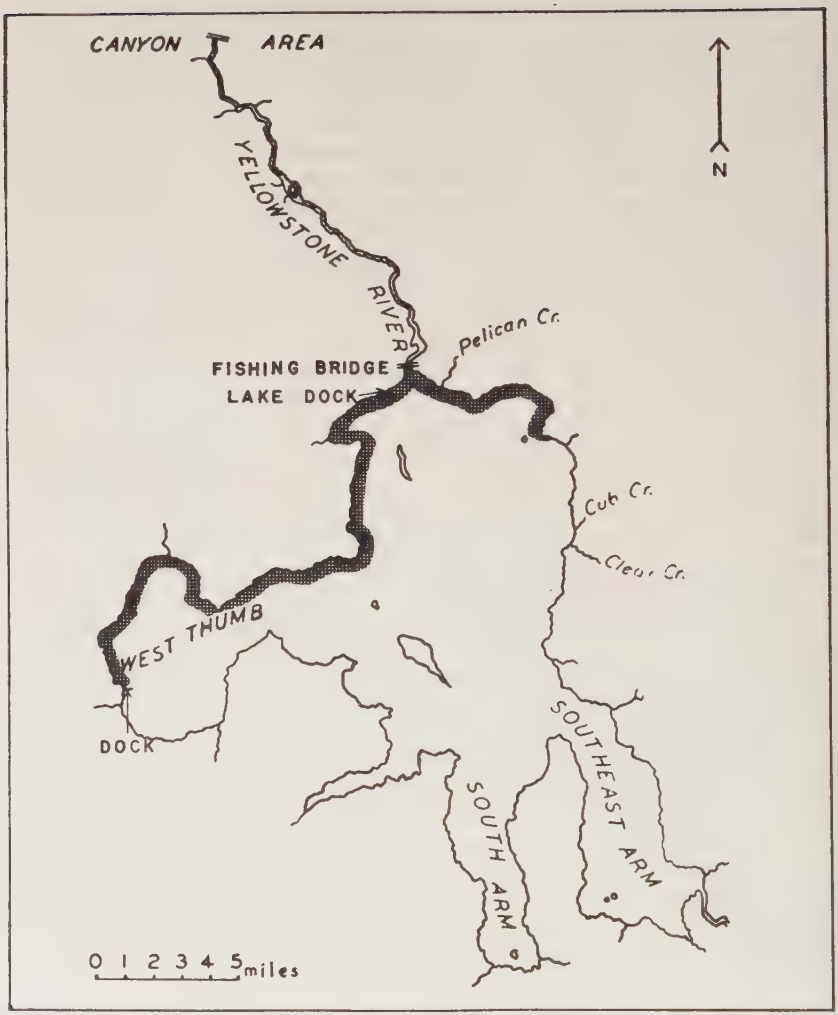

FIGURE 1.—Map of Yellowstone Lake and part of the Lower Yellowstone River, showing boat docks and other fishing landmarks. The shaded portion denotes the area involved in the shoreline fishery.

METHODS

Simple ratio estimates involving the application of sampling results to total numbers of anglers have been used to determine the total catch and the total effort for most elements of the fishery in all 6 years. Detailed data have been provided by the Yellowstone Park Company on numbers of

fishermen and numbers of boats rented at Fishing Bridge, Lake, and West Thumb. These data were supplemented by other information secured by sampling. The U. S. National Park Service furnished data on total boat permits issued for private trailer boats. The census method used for Yellowstone Lake shoreline and for Yellowstone River features the complete-incomplete census system described in the earlier paper.

There have been a few departures from the census methods used in 1951. The 1950–1951 method featured interviews at each boat dock, four times every two weeks. One innovation made in 1952 involved the use of a semi-volunteer census card system to replace the interview system. The objectives of the card system were to conserve manpower and increase the sample size. Questionnaire cards, shown in Figure 2, were handed to the fisherman when they paid their bills, and the boat dock cashier entered the fishing time on each card.

The card system was not adopted until the method had been tested at Fishing Bridge Dock. From May 30 through June 26, the interview and card censuses were conducted and a statistical comparison of the two methods was made (Table 1). There was no statistically significant difference between the two methods, so the semi-voluntary card system was adopted forthwith at both Fishing Bridge Dock and West Thumb Dock.

The shoreline census consisted of the incomplete census (touring the shoreline and counting fishermen) and the complete census (tabulating individual efforts and catches in one area throughout the entire fishing day). The frequency of incomplete censuses was increased from four to six per sampling period after 1951, and complete censuses were increased to six in each two-week period after 1952.

An important improvement in the Yellowstone River estimates was made by interviewing anglers after the fishing day was completed to determine average fishing time. Formerly the anglers had been interrogated before their fishing was terminated. The 1951 estimates have been revised in the light of this information.

One point should be mentioned in connection with time periods for 1952. The opening day for fishing on Yellowstone Lake in the first 3 years of investigation was May 30; the opening day in 1953–1955 was June 15. The second period of former years which began on June 13 is compared with the first period in 1953 although there is a 2 day discrepancy.

Hourly Distribution of Effort

Yellowstone Park is a resort area whose visitors usually stay in the park for several days during a visit. Many tourists move constantly during their stay in Yellowstone, but the great majority remain at resort centers such as Mammoth or Old Faithful for at least a few days before moving on. Tourists who camp in tents or trailers usually stay for several days to a month in one locality. The area bordering the lakeshore from West Thumb to the Fishing Bridge area is replete with living facilities for the semi-permanent, as well as the temporary Yellowstone visitors.

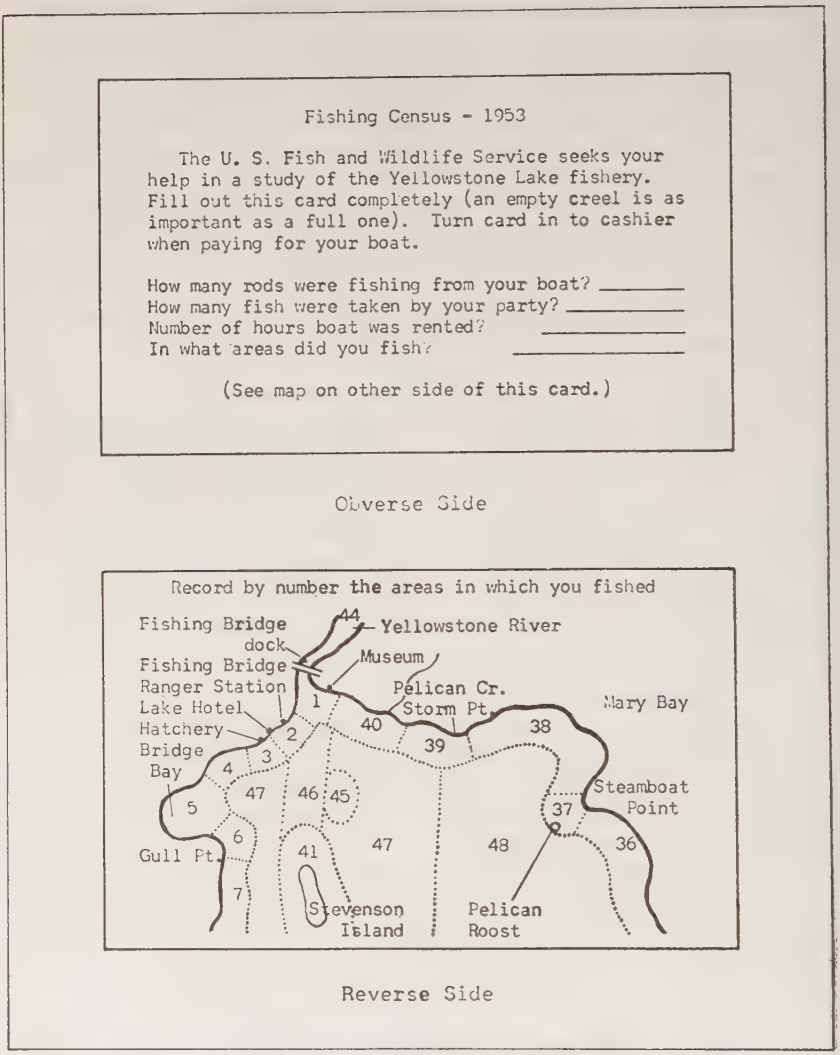

FIGURE 2.—Fishing census cards used for the rowboat fishery. The cards were filled out after the fishing had been completed.

This resort situation has a controlling influence upon the hourly and daily fishing pattern on Yellowstone Lake and River. Hours of fishing on Yellowstone Lake and River are limited by National Park Service regulations to the time between sunrise and dark. Sunrise is from 4:30 a.m. to 5:50 a.m. during the fishing season and nightfall occurs from 7 p.m. to

9 p.m. Anglers do not fish early in the morning but ordinarily appear between 7 and 8 a.m. However, a few anglers begin their fishing at the crack of dawn at Fishing Bridge. Private boats often remain at fishing sites until dark. The census was adjusted to the habits of the fishermen.

The distribution of fishing effort throughout the day is somewhat unusual on Yellowstone Lake. Most fisheries adhere to a bimodal distribution of effort such as that reported by Eschmeyer (1935) on Fife Lake, where there was a morning peak from 8 to 10 a.m. and an evening peak from 6 to 7 p.m. Smith (1950) reported a similar pattern on the Sacramento River in California, with peaks at 9 a.m. and 4 p.m.

TABLE 1.—*Comparison of results of two methods of estimating fishing success. Fishing Bridge Dock, May 30 — June 26, 1952*

Date	Catch per hour		Number degrees of freedom	t value
	Interview estimate	Card estimate		
May 30	0.2315	0.3597	88	1.179
June 3	1.1019	0.7490	43	1.057
do. 6	0.6530	0.8643	53	1.023
do. 7	0.3124	0.4598	92	1.372
do. 9	1.0681	0.9628	54	0.282
do. 13	0.5471	0.5314	50	0.008
do. 17	0.7820	1.3538	11	0.844
do. 20	0.9209	0.9407	58	0.078
do. 23	1.1466	0.7655	59	1.383

The daily distribution of fishing effort on Yellowstone Lake and Yellowstone River has been computed from angling hours measured throughout the complete seasons of 1952 and 1953. The 1952 patterns are shown in Figure 3. A definite trimodal pattern of distribution occurred for the lake and river in both years. Each curve shows fishing effort to be very low in the morning from 7 to 8 a.m., reaching a rapid, high peak in late forenoon, another lesser peak in the late afternoon, and a third one in the early evening. The morning and afternoon peaks were an hour earlier in 1953 than in 1952, but the evening peak occurred from 6 to 7 p.m. in both years.

Daily Distribution of Effort

Most sport fisheries are patronized far more heavily on weekends and holidays than on week days, a condition that has significance in the sampling schedule of the creel census. Smith's (1950) data showing effort and catch for the Sacramento River fishery from May, 1948 to February, 1950 are typical of the usual fishery. The average number of fishermen per day contacted and seen on Sundays and holidays was 64.3, on Saturdays, 49.1, and 25.2 on week days. Another example of great differences in fishing effort on Bear Lake, Idaho between week days and weekends of 1953 is provided by Mr. William McConnell, fishery biolo-

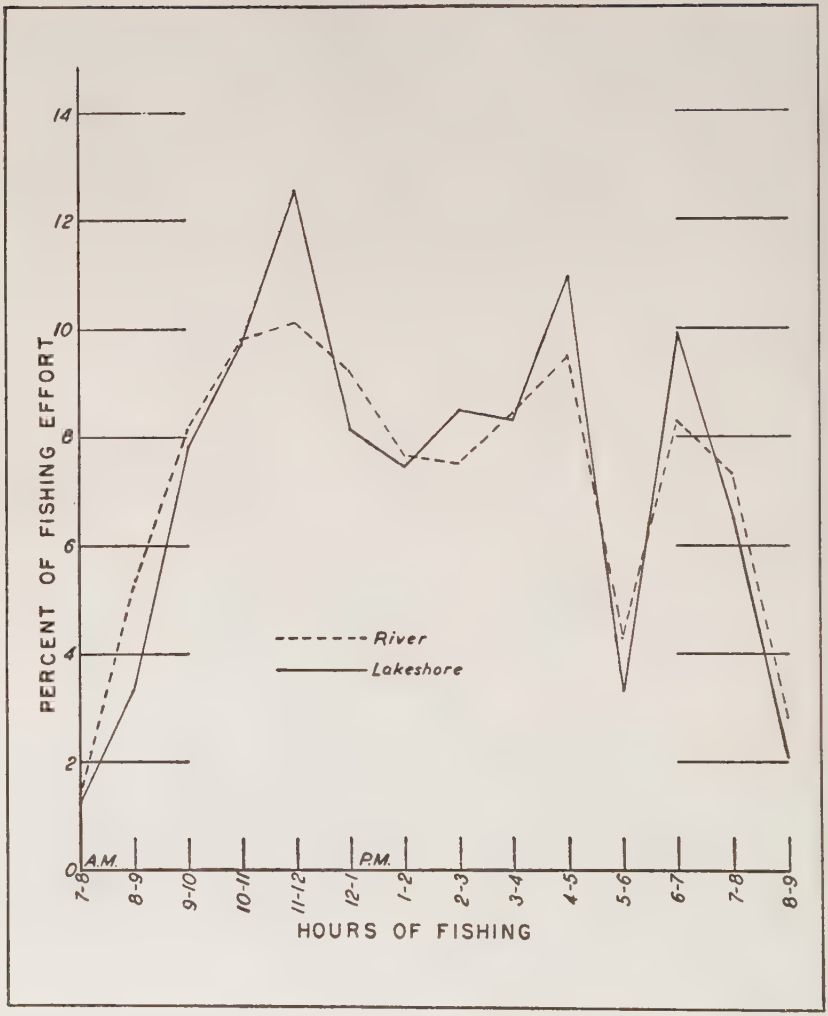

FIGURE 3.—Distribution of fishing effort by hours of the fishing day, for lakeshore and river, 1952.

gist of the Utah Department of Fish and Game, and Mr. William Clark, fishery biologist of the State of Idaho. The average number of anglers counted on Saturdays, Sundays, and summer holidays was 24.96 per day, and the average number of anglers per week day was 7.16.

The distribution of fishing effort on Yellowstone Lake follows a different pattern and again reflects the "resort" situation (Fig. 4). Rowboat and guideboat rentals at the various docks in 1953 were segregated according

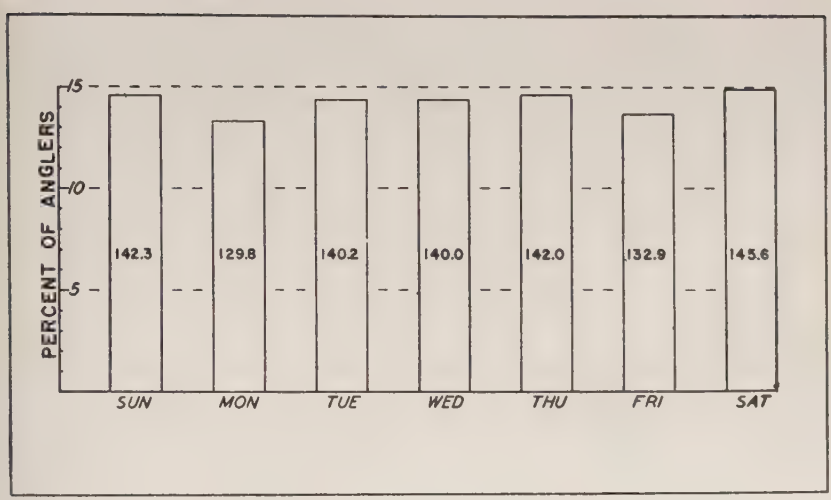

FIGURE 4.—Distribution of fishing effort, by days of the week, computed from numbers of fishermen using rowboats and guideboats from Fishing Bridge, Lake, and West Thumb docks in 1953. The figures in the bars represent average numbers of fishermen per day.

to days of the week for the entire season. These units were chosen as an illustration because of the completeness of the data. There was a strikingly uniform fishing pressure from day to day compared with the Bear Lake and Sacramento River fisheries. The day of greatest average fishing pressure at Yellowstone was Saturday and the lowest average pressure was on Monday. Weekend anglers from Cody, Wyoming, Idaho Falls, Idaho, and Livingston, Montana, do enter the park for Saturday and Sunday fishing, but in such small numbers that they may not significantly increase weekend fishing pressure. Their relatively high efficiency as anglers, however, probably considerably increases the total catch.

Sampling of the various units of the Yellowstone Lake and River fishery is relatively simple since all days can be treated alike. Weather remains as the largest single influence on fishing intensity from hour to hour and from day to day.

Distribution of Effort According to Area and Season

Some areas of the Yellowstone fishery exhibit constant patterns year after year, and knowledge of these patterns has value in the management of the fishery. An example of this tendency is found in 4 years' rowboat catch data from Fishing Bridge fishery area and West Thumb fishery area (Fig. 4). The catch in the Fishing Bridge area quickly builds up to a peak at the end of June and immediately begins a decline which persists to the end of the season. The West Thumb fishery, in contrast,

increases slowly from the beginning of the season until the middle of August, at which time a sharp decline begins. The West Thumb fishery, then, is relatively small but sustained, while the Fishing Bridge area fishery peaks rapidly and declines quickly. The Fishing Bridge area fishery is of greater magnitude than is the West Thumb fishery, throughout the entire season.

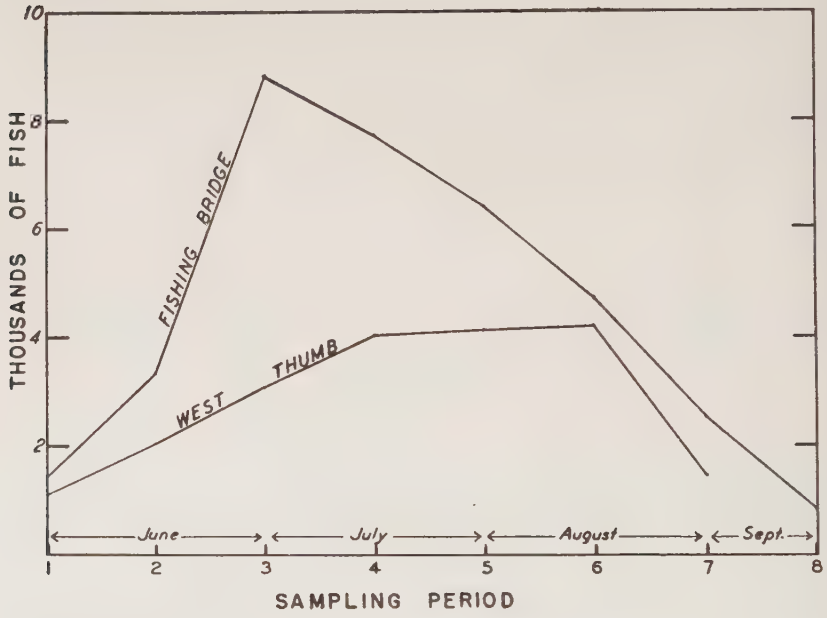

FIGURE 5.—Catch, in thousands of fish, plotted against sampling periods throughout the season, for the Fishing Bridge fishing area and the West Thumb fishing area. Catch figures are based on rowboat landings, and are mean annual catches for the years 1950–1953.

These curves can be explained on the origin of the fish entering the fisheries. The Fishing Bridge area fishery is strongly influenced by spawning migrations to Fishing Bridge, Pelican Creek, Clear Creek and Cub Creek. The height of the migration of spawners coincides with the peak catch in the Fishing Bridge area. On the other hand, the West Thumb fishery is not influenced by spawning migrations, since there are no streams supporting large runs in this area. A large portion of the fish taken in the West Thumb fishery enter the area after having spawned in other places, an observation supported by tagging studies. The delays encountered in getting back to the lake after spawning and in moving northward account for the sustained harvest in the West Thumb fishery.

Census Results

Fishing Bridge Dock.—Fishing Bridge Dock occupies an important place in the fishery scheme on Yellowstone Lake. It is located 50 yards downstream from Fishing Bridge and a half mile downstream from the outlet of Yellowstone Lake. The dock is situated so that fishermen can utilize the lake, the intermediate area between lake and river, and the upper end of the Yellowstone River proper. This dock rents more rowboats than does either Lake Dock or West Thumb Dock, and more fish are landed here than elsewhere. Lake Dock, located a mile west of Fishing Bridge Dock, specializes in guide boat fishing, has some rowboat rentals, and also caters to private boats.

The most noticeable features of the rowboat data are the high catch-per-hour value for 1952 and the low fishing effort for 1953–1955 (Table 2). The reduced effort of 1953 was undoubtedly related to the lowered limit, the shortened season, and poor weather in June. Travel to the park was only 1.7 percent lower than in 1952, while fishing effort on Yellowstone Lake was 27.2 percent lower.

The guideboat fishery from Fishing Bridge Dock was eliminated after 1953. Different annual rates of fishing success resulted in total catches in this fishery varying from 19,000 to 26,000 fish from 1950 to 1953. The general trend in fishing success in this element of the fishery was downward, and suggests a decrease in the availability of fish to guide boat anglers. The average hours fished, per fisherman, decreased from 2.20 hours in 1950 to 1.84 hours in 1953.

A noteworthy difference in fishing success between rowboats and guideboats appeared each year. The highest catch-per-hour measurement for rowboats at Fishing Bridge Dock was 0.735 in 1952, while the lowest recorded for the guideboats was 1.441 in 1953. The advantage in favor of guideboats can be attributed to the skill of the fishing guides and to the ability of guide boats to penetrate to good fishing areas not accessible to the smaller rowboats.

West Thumb Dock.—The rowboat fishery of West Thumb Dock fluctuated moderately in effort from 1950 to 1955 (Table 3). The catch-per-hour was fairly uniform with only a slight reduction in 1952. Fluctuations in total catch were mainly functions of effort expended, except in 1952. Rowboat fishing success at West Thumb was about the same as at Fishing Bridge Dock, although the angling effort was considerably lower at the former location.

Guide boats at West Thumb underwent a decline from 1.785 to 1.120 in catch-per-hour from 1950 to 1953, but rose to 2.280 by 1955. Effort and catch were considerably less than at Fishing Bridge, but success was only slightly lower. Guide boats had a fishing success more than twice as great as that for rowboats, as at Fishing Bridge.

Lake Dock.—Fishing activity at Lake Dock was emphasized by the concessionnaire in 1954 and 1955. Guide boats at this location replaced those at Fishing Bridge Dock, and rowboat rentals increased. Results

TABLE 2.—*Creel census results, Fishing Bridge Dock, 1950—1955*

Year	Sampling results					Yellowstone Park Company records		Estimates	
	Number of fishing parties	Number of fishermen	Number of fishermen hours	Catch	Average catch per man hour	Number of fishing parties	Number of fishermen	Total fisherman hours	Total catch
				Rowboats					
1950	3,633	8,202	21,716.3	11,456	0.528	10,330	25,727	68,177	35,997
1951	2,031	4,847	14,112.6	6,513	0.462	9,162	27,578	80,252	37,076
1952	1,436	3,498	11,215.7	8,243	0.735	7,293	21,587	69,294	50,931
1953	1,436	3,547	9,541.4	4,608	0.483	6,900	17,642	47,509	22,938
1954	2,341	5,985	15,005.8	7,698	0.513	5,906	15,102	41,804	21,461
1955	3,398	8,073	24,340.5	11,294	0.464	7,204	17,117	49,440	22,920
				Guideboats[1]					
1950	602	1,934	4,254.0	8,482	1.993	1,422	5,016	11,035.2	21,960
1951	1.102	3,679	7,484.3	16,287	2.176	1,620	5,882	11,940.5	26,029
1952	576	2,014	5,292.7	8,361	1.580	1,614	5,389	14,173.1	22,393
1953	638	2,308	4,256.0	6,134	1.441	1,978	7,177	13,203.4	19,025

[1]Guideboats not fished from Fishing Bridge Dock in 1954 or 1955

TABLE 3.—*Creel census results, West Thumb Dock, 1950—1955*

Year	Sampling results					Yellowstone Park Company records		Estimates	
	Number of fishing parties	Number of fishermen	Number of fishermen hours	Catch	Average catch per man hour	Number of fishing parties	Number of fishermen	Total fisherman hours	Total catch
Rowboats									
1950	1,316	3,222	9,911.2	5,234	0.528	4,692	11,761	36,224	19,126
1951	952	2,336	6,654.0	3,971	0.597	4,769	14,057	40,062	23,917
1952	2,106	5,146	20,295.9	8,798	0.434	4,595	13,936	54,908	23,830
1953	558	1,306	3,679.0	1,953	0.531	4,115	10,574	29,819	15,834
1954	2,185	5,418	16,025.1	7,644	0.477	4,565	11,321	32,864	15,678
1955	669	1,696	5,024.3	2,797	0.566	4,892	12,400	36,755	20,817
Guideboats									
1950	171	581	1,350.7	2,411	1.785	470	1,507	3,511	6,268
1951	63	218	507.6	664	1.307	311	1,123	2,617	3,420
1952	137	494	1,299.2	2,054	1.581	353	1,216	3,198	5,056
1953	290	1,126	2,494.0	2,794	1.120	515	1,845	4,078	4,567
1954	215	628	892.9	1,751	1.961	436	1,272	1,850	3,627
1955	104	417	547.4	1,248	2.280	875	3,500	4,630	10,562

measured at Lake Dock were: Guideboats, 1954, 17,155 hours of effort, and a catch of 28,773 fish; 1955, 21,713 hours of effort, and a catch of 30,922 fish. Rowboats, 1954, 4,456 hours of effort, and a catch of 2,830; 1955, 5,748 hours of effort and a catch of 4,249.

Fishing Bridge.—The yearly catches generally reflect the amount of fishing effort at Fishing Bridge (Table 4). Catch-per-hour showed a downward trend from 1950 to 1953, but increased in 1954–1955. In all years, catches from Fishing Bridge were closely associated with spawning

TABLE 4.—*Creel census results, Fishing Bridge, 1950—1955*

Sampling results				Estimate	
Year	Rod hours	Catch	Catch per rod hour	Total rod hours	Total catch
1950	3,408	556	0.163	39,372	6,417
1951	10,395	1,647	0.158	41,613	6,575
1952	9,103	1,258	0.138	35,256	4,865
1953	11,580	1,504	0.130	41,448	5,388
1954	13,484	2,225	0.165	42,744	7,072
1955	10,506	1,760	0.168	36,771	6,165

migrations in Yellowstone Lake and River. Consequently, the fishery has been most successful for about three weeks following the July 1 opening date.

Lakeshore.—The census on the lakeshore was conducted in accordance with the methods described in the earlier report. In the cases of the second and third periods of 1952, an irregularity in sampling resulted in estimates that were obviously too high. Revised catch and effort estimates were therefore substituted for these values, and appear in Table 5. The results of this census show fair agreement in success from year to year. The catch of 1955 was the largest, but angling success was highest in 1950. Calculations of standard deviation appear in Table 5. The census shows increases in the amount of fishing and the catch-per-unit-effort data suggest no diminution in the population available to the fishery.

TABLE 5.—*Creel census results, Yellowstone Lake shoreline, 1950—1955*

Year	Number of fishermen	Number of fisherman hours	Standard deviation	Number of fish	Standard deviation	Catch per fisherman hour
1950	50,260	85,281	[1]	55,370	[1]	0.649
1951	114,743	120,651	±6,387.0	48,965	±8,474.4	0.406
1952	110,997	132,113	[2]±3,653.1	53,423	[2]±3,287.0	0.404
1953	82,447	112,914	±3,521.6	64,116	±2,572.3	0.522
1954	71,068	116,804	±2,286.3	71,919	±1,967.2	0.616
1955	87,156	175,149	±3,784.5	97,831	±2,967.7	0.559

[1]No standard deviation estimated because of census method
[2]Estimates derived by other than the usual method

Trailer boat fishery.—The volunteer boat card method described in the former report was also used successfully in 1952–1955. The cards were issued to private boats as they entered the park, the fishermen recorded information on catch and effort, and the cards were returned at the park gates when the boats left the park. More than 25 percent of the cards issued in each year were returned. The greatest use of small, trailer-type boats was made in 1955, with 2,691 boat trips on Yellowstone Lake carrying 9,284 fishermen. This important part of the Yellowstone Lake fishery has shown a steady decline in fishing success over the 6-year period (Table 6).

Cruiser fishery.—The number of large private boats (20 to 30 feet) used for fishing on Yellowstone Lake has increased from year to year, and in 1954 nearly reached the maximum dock and anchorage capacity on the lake. The cruiser catch is the poorest known unit of the Yellowstone fishery because of the unwillingness of many boat operators to keep catch records. It was necessary to base estimates on records for only a few boats for 1950. The 1953–1955 catch estimates are based on the time each boat was used on the lake, the number of passengers in each boat, and the assumption that limit catches were made by nearly each person each day. The 1953 catch for cruisers on Yellowstone Lake greatly surpassed those for previous years, but the 1954 and 1955 catches were a little lower. It was not feasible to compare year-to-year fishing success in this element of the fishery. Cruiser catch estimates are shown in Table 7.

Yellowstone River.—The method for censusing the Yellowstone River after 1951 featured a modification of the lakeshore method. The 1951 values were adjusted in accordance with the average fishing time per person measured in 1952 and 1953 (Table 8). The numbers of fishermen on the river increased up to 1953 and then decreased, but effort did not change in proportion. Catch-per-hour was 0.649 in 1955, which surpassed all previous years.

The Lake Outlet.—Yellowstone Lake and Yellowstone River meet in a boundary area which seems to be ecologically different from either lake or river. The boundary is defined as the region between Fishing Bridge and 300 yards downstream. It is fished by rental and private boats and fishermen angling from the bridge. The area supports more fishing pressure and a greater catch than any other place on the lake or river of comparable size. The average annual hours of fishing for Yellowstone Lake and River are 454,703 hours (cruisers excepted), and the boundary area fishing was 150,042 or 33 percent of the lake and river combined. With respect to catch, the average annual harvest of Yellowstone Lake and River was 288,519 fish and the boundary area harvest was 75,009 fish, or 26 percent.

Yellowstone Lake and River offer about 50 miles of shore fishing and over 100 square miles of water for boat fishing. Yet, 33 percent of the fishing effort and 26 percent of the catch were concentrated at the boundary area. The area adjacent to Fishing Bridge is thus regarded as the most important fishing area of its size in the drainage. It should be

TABLE 6.—*Creel census results, trailer boat card census, 1950—1955*

Year	Average days on lake	Average anglers in boat	Average catch per boat day	Number boat trips on lake[1]	Number of fishermen	Efforts (hours)	Catch estimate	Catch per hour
1950	[2]2.85	[2]3.24	[2]12	1,473	4,773	49,389	50,377	1.020
1951	2.85	3.24	12	1,604	5,197	55,954	54,857	0.980
1952	2.94	3.28	10.18	2,619	8,590	94,047	75,457	0.802
1953	3.35	3.23	7.39	1,979	6,392	73,713	50,118	0.680
1954	3.41	3.40	8.21	1,831	6,225	75,327	51,222	0.680
1955	3.58	3.45	8.33	2,691	9,284	115,000	80,270	0.698

[1]Including re-entry trips
[2]Rates assumed to be the same as for 1951

considered as an intermediate zone, apart from Yellowstone Lake and from the rest of Yellowstone River. This area supports a tremendous spawning concentration from both the lake and river and the anglers take advantage of these unusual concentrations of fish.

TABLE 7.—*Creel census results, cruiser type boats at West Thumb, Lake and Fishing Bridge Docks, 1950—1955*

Year	Number of boats	Estimated number of trips	Catch estimate
1950	15	.....	4,500
1951	11	.....	5,052
1952	23	.....	9,322
1953	64	1,257	13,887
1954	89	1,557	13,351
1955	87	1,508	12,320

TABLE 8.—*Creel census results, Yellowstone River, 1951—1955*

Year	Number of fishermen	Fisherman hours	Standard deviation	Catch	Standard deviation	Catch per hour
1951	[1]26,713	83,614	±3,527.9	19,729	±3,388.6	0.236
1952	31,694	91,437	±2,802.6	20,603	±3,363.9	0.225
1953	59,395	80,664	±2,163.4	27,932	±2,258.1	0.346
1954	39,684	75,134	±1,533.5	35,912	±1,517.9	0.478
1955	49,087	75,692	±2,243.6	63,701	±5,764.3	0.649

[1]Adjusted from figures formerly published

TRENDS IN THE FISHERY

Postwar travel to Yellowstone increased each year up to 1952, except for a small decline in 1950. The 1953 count of tourists was slightly below the travel peak attained in 1952, but increases ocurred in 1954 and 1955. The trends in travel were reflected in the amount of fishing on Yellowstone Lake and River; measurements of hours of fishing pressure showed a peak in 1952, followed by a decrease in 1953 and increases in 1954 and 1955.

Numbers of tourists to Yellowstone were 1,109,926 in 1950, 1,166,346 in 1951, 1,330,387 in 1952, 1,326,858 in 1953, 1,328,893 in 1954, and 1,368,515 in 1955. Changes in fishing pressure followed those for tourist pressure at Yellowstone, with the following total numbers of angling hours computed for Yellowstone Lake: 292,989 in 1950, 353,090 in 1951, 402,989 in 1952, 332,684 in 1953, 333,004 in 1954, and 445,206 in 1955. Total catch figures for Yellowstone Lake were: 200,015 in 1950, 208,255 in 1951, 245,277 in 1952, 195,873 in 1953, 215,933 in 1954, and 286,056 in 1955, showing that catch totals were roughly proportional to those for travel to the park. The exception to this relationship was in 1953, when restrictions were placed on the fishery and a decrease in effort and catch resulted.

The elements of the fishery subjected to the greatest fishing pressure from year to year were the Fishing Bridge rowboats, private trailer boats, and the lake shoreline, although not always in that order. The portions of the fishery enjoying the greatest fishing success were the West Thumb, Lake and Fishing Bridge guide boats and the private trailer boats. It is judged that private cruisers had a fishing success similar to that for guide boats, although good measurements are not at hand.

The effects of changed regulations in 1953 were twofold: the shortened season and three-fish limit had a direct effect by reducing total seasonal fishing effort, and an indirect influence through a reduction in numbers of fishermen attracted to Yellowstone. The three fish limit definitely did not attract fishermen from nearby states to the extent that the former larger limits had done. These factors caused a 20 percent decrease in angling pressure in 1953, even though the West Thumb guide boats and Fishing Bridge increased in total hours of fishing. The catch was likewise decreased, but to a lesser degree than the effort. Figure 6 shows the relationship between travel to Yellowstone and fishing pressure on

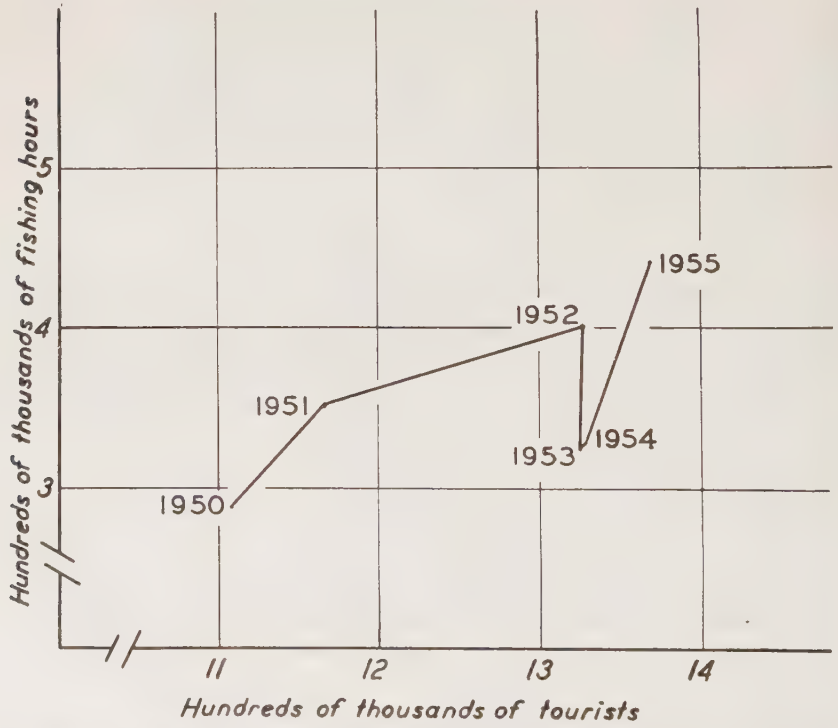

FIGURE 6.—Fishing effort plotted against numbers of tourists visiting Yellowstone Park, from 1950 to 1955. Fishing effort includes all elements of the fishery on Yellowstone Lake and Yellowstone River.

Yellowstone Lake, with fishing pressure increasing at a faster rate than travel from 1950 to 1951. The rate was reduced in the next year, and both travel and effort declined from 1952 to 1953. From 1953 to 1954 there was little change, but in 1955 fishing effort increased greatly in relation to increased travel. The shortened season would seem to be the most important factor in the decline of fishing effort.

The direct effects of reduced limits alone are important in the light of total catch. The distribution of limit and sub-limit catches for the years 1952 and 1953 are depicted in Figure 7.

In 1953, when the three fish limit was in effect, the percentages of limit catches were higher than in 1952, and there was no large reduction in total catch due to this regulation. Figure 7 shows that the combined values of 3, 4, and 5 fish catches in 1952 amount to about the same as the limit catches of 1953, and lower catches were similar in both years. So,

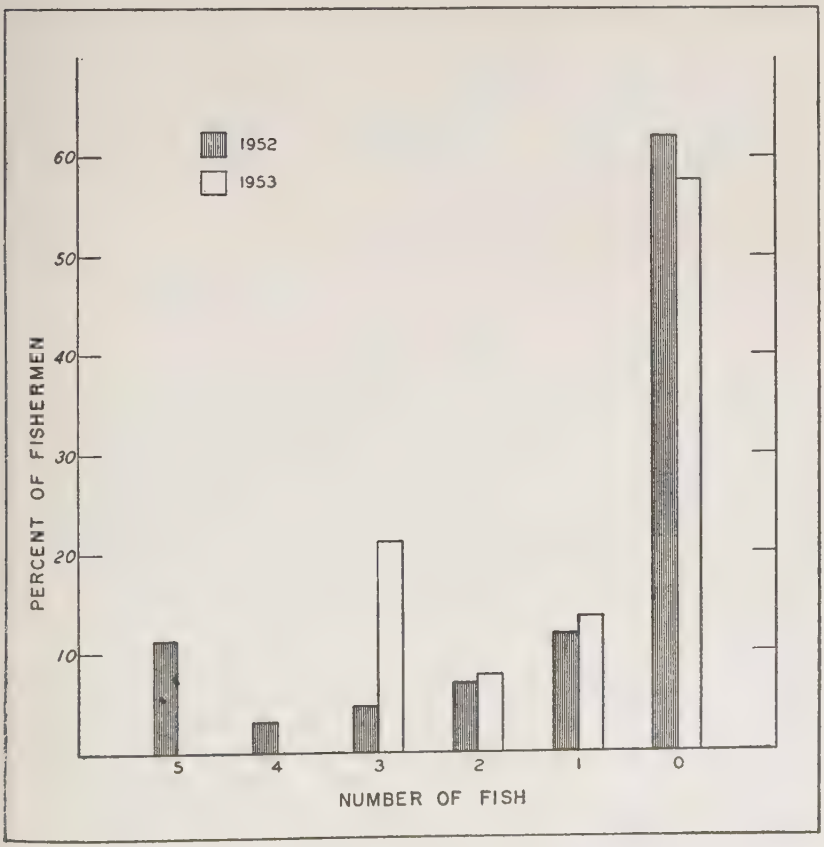

FIGURE 7.—Percentages of fishermen catching numbers of fish.

the lowering of the limit did not reduce the total catch in this case, but merely rearranged the distribution.

Annual Yield

Annual yield is commonly expressed in creel census studies in terms of the average number of pounds of fish harvested per acre of water. The Yellowstone Lake fishery does not lend itself to this kind of treatment, because of the uneven distribution of fishing pressure on the lake as indicated previously and because of the dependence of the fishery on concentrations of fish on spawning migrations. Some geographical units of the lake seem to harbor certain portions of the fish populations, according to the results of tagging, and they are treated individually.

The area of most concentrated effort and catch is the water from a point 300 yards below Fishing Bridge to a point a half mile above the bridge. This includes part of the lake proper. This area annually averaged 145.22 pounds of fish caught per acre for the years 1951, 1952, and 1953. The area served by the Fishing Bridge boat dock, comprising 6,555 acres and extending from a point 300 yards below Fishing Bridge to parts of the lake several miles from Fishing Bridge yielded 15.15 pounds per acre during these years. The West Thumb of Yellowstone Lake, with 11,345 acres, had an average annual yield of 3.37 pounds per acre. The whole of Yellowstone Lake, including the large central area, and the lightly-fished arms in the south part, yielded 1.75 pounds per acre annually for the three year period. It is apparent that none of the above figures is a true index of the productivity of Yellowstone Lake, but they can be used for comparative purposes.

Sizes of Fish

Length measurements indicate that from 1950 to 1952 the lengths of fish landed in the Fishing Bridge area and the West Thumb area decreased significantly (Cope, 1953). Fish caught in the Fishing Bridge area in 1952 had a mean total length of 338.1 millimeters, a figure that is considerably higher than the West Thumb size of 323.6 millimeters. The 1953 collections were found to have larger fish than those of 1952. Fish from the Fishing Bridge area in 1953 had a mean total length of 360.8 millimeters, and the West Thumb samples averaged 331.8 millimeters. Relatively large mean lengths persisted in the fisheries of 1954 and 1955.

The increase in 1953 of average fish length is probably attributable to the recruitment of two weak year classes. The declines in mean length noted in 1951 and 1952 were due in a large part to the entrance into the late season fishery of numbers of small fish measuring 300 millimeters (11.8 inches) or less. There had been ample evidence of increasing numbers of these smaller fish in the fishery since 1948, especially toward the ends of the angling seasons, and their influence on mean lengths of the catch was great. The 1953 fishery landed fewer of this size group than did

the fisheries of 1951 and 1953. Furthermore, a trap net fished near Fishing Bridge in 1952 and 1953 took less of these 12-inch fish in 1953 than in 1952. In 1952, 23.3 percent of the trap net catch consisted of fish 300 millimeters (11.8 inches) or less in length, while in 1953, only 6.2 percent of the catch were in this size group. This suggests that the fish of the 1950 and 1951 broods represent weak year classes, and accounts for the increase in mean length of the 1953 fishery.

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THE USE OF TOXAPHENE AS A FISH POISON[1]

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ABSTRACT

Standard laboratory bio-assay tests on the insecticide toxaphene indicated that this chemical is more toxic to fish in hard water than in soft water. Its toxicity to the bluntnose minnow was increased approximately three-fold by raising the temperature from 50° F. to 75° F. This insecticide was found to be much more toxic to the bluntnose minnow than to any of four aquatic invertebrates tested. The laboratory work supported field observations on two Michigan lakes. Many groups of invertebrates were killed by toxaphene treatment, but they reappeared while the lake water was still toxic to fish.

Detoxification of water stored in the laboratory proceeded most rapidly when it was exposed to light, when the oxygen content was high, and when the temperature was high. Hard water (alkalinity, 212 p.p.m.) detoxified more rapidly than soft water (alkalinity, 6 p.p.m.). Detoxification was greatly accelerated by water movements which brought the toxicant in contact with the walls and bottom of the aquarium. The rate of detoxification was increased by the addition of a substrate of glass marbles or gravel. Sand and mud assisted detoxification to a lesser extent. Sterilization of the substrate with dilute formalin and carbolic acid inhibited detoxification; this indicated that microorganisms were responsible for reducing toxicity.

INTRODUCTION

The use of the insecticide toxaphene (chlorinated camphene) as a fish poison has recently aroused considerable interest among fisheries workers. The present work was undertaken to study the influence of environmental conditions upon the toxicity of this chemical to fish and fish-food organisms. Information of this type is needed before toxaphene can be used safely in the field.

Toxaphene was recognized as a fish toxicant when dead fish appeared in waterways adjacent to fields which had been sprayed or dusted with the chemical (Lawrence, 1950; Tarzwell, 1950). Extensive laboratory tests have placed the lower limits of toxicity from 0.2 p.p.m to less than 0.005 p.p.m. depending upon the species of fish, the location of the experiments (aquaria or earthen pond), and other variable experimental conditions. Duodoroff, Katz, and Tarzwell (1953) estimated that the median tolerance limit of goldfish exposed to toxaphene dust for 24 hours was about 0.025 p.p.m. The 10-day median tolerance limit of goldfish was estimated to be somewhat below 0.005 p.p.m. Lawrence (1950) found that a concentration of 0.05 p.p.m. killed goldfish, largemouth bass, and bluegills

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in aquaria, but this concentration did not kill the same species in an earthen pond. Surber (1948) found that a concentration of 0.02 p.p.m. did not kill goldfish but was lethal to 10 other species of freshwater fish. Trout fingerlings were killed at a concentration as low as 0.005 p.p.m. Tanner and Hayes (1955) reported that a variety of concentrations ranging from 0.05 to 0.2 p.p.m. killed carp in about the same length of time (180 minutes). Both the laboratory test of Duodoroff, Katz, and Tarzwell (1953) and the field trials of Tanner and Hayes (1955) have indicated that long exposure periods are required to kill fish in the lower ranges of concentration. Many of the discrepancies in reported values for toxicity doubtlessly can be traced to the fact that laboratory tests have been of short duration.

Confusion concerning lethal concentrations of toxaphene has perhaps been in part responsible for the difficulties encountered in using it for fish eradication. On the basis of experiments showing that 0.1 p.p.m. of toxaphene killed carp at 65° F. in 72 hours, Hemphill (1954) used this concentration in treating two shallow Arizona lakes. These lakes apparently detoxified promptly. The concentration used by Hemphill (0.1 p.p.m) is 20 times greater than the estimated 10-day median tolerance limit to goldfish given by Duodoroff, Katz, and Tarzwell (1953). This suggests that Hemphill's recommended dosage is high and that it might be reduced considerably if the influence of various field conditions upon toxicity is known.

Hemphill believed that the pH of the water influenced the breakdown of toxaphene. He found that alkaline waters lost their toxicity within four weeks. Other workers, however, have noted that toxicity may persist longer in alkaline waters. A reservoir treated by Tanner and Hayes (1955) remained toxic to fish for more than seven months at a pH greater than 8.0. A Michigan lake (Horseshoe Lake, Alcona County) with a pH of 8.2 treated with a concentration of 0.1 p.p.m. remained toxic for 10 months. The effect of water hardness upon the toxicity and upon the rate of detoxification of toxaphene and related compounds is not known. Temperature has a profound influence upon the effectiveness of rotenone (Leonard, 1939), and light probably also influences the rate of dissipation of rotenone-bearing fish poisons (Clemens and Martin, 1953). Data concerning the influence of these conditions upon toxaphene are needed.

The influence of toxaphene upon fish-food organisms has not been fully explored. Hemphill (1954) stated that insects are severely affected but not eliminated by it. He suggested that the reappearance of zooplankton may be used as an indication that a lake has detoxified. Tanner and Hayes (1955), however, noted that zooplankters were present before water lost its toxicity to fish.

Methods

The methods which were used in the toxicity studies followed closely those recommended by Doudoroff *et al.* (1951). The test fish were the bluntnose minnow (*Pimephales promelas*) and the creek chub (*Semotilus*

atromaculatus). They were carefully selected to range in length between 2.0 and 2.5 inches. Prior to the trials, fish were conditioned for 48 hours at the test water temperature. Two gallons of test water per minnow were used in all determinations of the median tolerance limit. It was necessary to determine whether or not this ratio of water to fish was sufficiently high to avoid detoxification of the water by the fish themselves. After tests were completed at the lowest concentrations (0.003 and 0.005 p.p.m.), the same water was retested with a second group of fish. The average survival time of the second group did not differ significantly from the average survival time of the first group. The fish had no influence on the toxicity of the solution.

Controls were maintained for all experiments. Results were disregarded when more than 10 percent of the control animals died during tests in which the median tolerance limit was being determined. Only natural waters were used. "Hard" water was taken from Fleming Creek, Washtenaw County, Michigan which had a methyl orange alkalinity ranging from 200 to 212 p.p.m. The "soft" water from Weber Lake, Cheboygan County, Michigan had an alkalinity of 6 p.p.m. Temperature was maintained at a constant level by immersing aquaria in a water bath whose temperature was thermostatically controlled. The maximum temperature fluctuation was less than 5° F. The concentration of dissolved oxygen remained above 5 p.p.m. in the unaerated aquaria.

The 24-hour median tolerance limit (TLm) was used to compare absolute toxicities (Litchfield and Wilcoxon, 1949). Percentages of animals surviving 24-hour test periods at various concentrations were plotted on logarithmic probility paper (Codex 3128). Ten experimental animals were used at each concentration tested. If either 100 percent or 0 percent survived, a corrected percentage was plotted from a table of maximal and minimal corrected probits. A straight line was then fitted by inspection to the plotted points. In fitting this line, points in the 30 percent to 70 percent range of survival were weighted most heavily. The fit of the line to the data was tested by chi square. If the fit was poor, a second line was drawn and tested. The median tolerance limit was determined by reading the concentration at which the fitted line intercepted the 50 percent survival ordinate, and confidence limits were computed (c.f. Litchfield and Wilcoxon, p. 102).

Invertebrates were conditioned for 48 hours at the experimental temperature before they were used in experiments. *Daphnia magna* were secured from the laboratory culture maintained by the Department of Zoology, University of Michigan. Only early instars of *Daphnia* were used. All other invertebrates were collected in the field. Mayfly nymphs (*Ephemera simulans*) were taken from Cedar Lake, Washtenaw County, Michigan. *Asellus intermedius* and *Gammarus fasciatus* were obtained from Houghton Creek, Ogemaw County, Michigan.

The toxaphene used in all experiments was an emulsified concentrate marketed under the trade name Cooper-Tox, by William Cooper and Nephews, Chicago, Illinois. It contains six pounds of technical toxaphene per gallon.

Influence of Alkalinity and Temperature upon Toxicity

The 24-hour median tolerance limit (TLm) of the bluntnose minnow to toxaphene increased from 0.02 p.p.m. in hard water to 0.036 p.p.m. in soft water at a temperature of 50° F. (Table 1). Both of the test waters were alkaline during the trials. The pH of the hard water remained practically constant at 8.6 but the pH of the soft water fluctuated from 8.1 to 7.4 during the experiments.

The effect of temperature upon toxicity was more pronounced. The 24-hour TLm increased from 0.0057 p.p.m. at 75° F. to 0.020 p.p.m. at 50° F. (Table 1). Similar increases in potency with increasing water temperatures have been noted in the case of rotenone (Leonard, 1938; Burdick, *et al.*, 1955).

Comparative Toxicity to Invertebrates

Invertebrates of a uniform size were tested in hard water at 55° F. At this temperature, laboratory stocks could be maintained and there was little or no mortality among control animals during experiments. At a lower temperature (45° F.) *Daphnia* became quiescent and so insensitive to the chemical that a 24-hour TLm could not be determined.

All invertebrates had much higher TLm values than the bluntnose minnow. *Gammarus* was most sensitive to toxaphene, but its TLm at 55° F. (0.06 p.p.m.) was three times higher than that of the bluntnose minnow at 50° F. (0.02 p.p.m.). Nymphs of the mayfly *Ephemera simulans* were most tolerant of the chemical; nearly 10 p.p.m. were required to kill 50 percent of the nymphs in 24 hours. The observation of Tanner and Hayes (1955) that lakes treated with toxaphene may support large populations of *Daphnia* while they are toxic to fish is well substantiated. The 24-hour TLm of *Daphnia* at 55° F. was 75 times greater than that of the bluntnose minnow at a temperature of 50° F. These results indicate that *Daphnia* can survive in solutions of toxaphene strong enough for fish eradication.

A large portion of the benthos was killed in a month in two Michigan lakes treated with 0.1 p.p.m. toxaphene (Table 2). In Horseshoe Lake, mollusks (Unionidae, Sphaeriidae, gastropods) and certain aquatic oligochaetes (Tubificidae) were the only groups which did not appear to be harmed. A few midges and mayflies survived for more than three weeks (September 21-October 15), but these species were not collected the following spring.

Repopulation by most groups of invertebrates was well underway by mid-summer of the year following treatment. In Horseshoe Lake, dragonfly nymphs reappeared in abundance by July 29, although many of the aquatic diptera, e.g. *Chaoborus,* were not present. Eleven months after treatment, McCarthy Lake had a greater standing crop of benthos than existed prior to treatment. At this later time, the bottom fauna was almost entirely a single species of midge (*Tendipes plumosus*). The spectacular repopulation of the lake bottom was probably hastened by the absence of fish and other predators.

TABLE 1.—*The 24-hour median tolerance limit (TLm) of certain invertebrates and fish to toxaphene*

[Six concentrations were used in determining each TLm]

Species	Methyl orange alkalinity (p.p.m.)	Temperature (°F.)	TLm (p.p.m.)	Confidence interval (0.95)
Pimephales promelas	6	50	0.036	0.026—0.050
Pimephales promelas	212	50	0.020	0.014—0.028
Pimephales promelas	212	75	0.0057	0.0041—0.0080
Gammarus fasciatus	212	55	0.060	0.014—0.22
Asellus intermedius	212	55	0.10	0.029—0.34
Daphnia magna	212	55	1.5	0.79—2.8
Ephemera simulans	212	55	9.5	5.6—16.0

TABLE 2.—*Invertebrates collected with an Ekman dredge before and after treating two Michigan lakes with toxaphene (0.1 p.p.m.)*

Location and date of sampling	Number of samples	Average number of animals per square foot						
		Diptera	Ondonata	Ephemeroptera	Oligochaeta	Mollusca	Miscel-laneous	All organisms (total)
Horseshoe Lake[1]								
Sept. 20, 1954 (Before treatment)	12	92	6.4	48	0.5	1.78	3.0	156
Oct. 15, 1954	12	15.6	....	4.0	4.8	4.8	0.40	29.2
April 29, 1955	6	0.4	....	...	1.2	0.8	...	4.0
July 29, 1955	6	3.4	10.8	...	10.8	6.4	...	31.2
McCarthy Lake[2]								
Aug. 3, 1954 (Before treatment)	15	428	....	1.2	....	....	0.4	43.2
Aug. 24, 1954	6	0.64	....	...	0.64	0.6	...	1.9
May 25, 1955	6	....	....	...	4.4	...	...	4.4
June 23, 1955	6	916	....	...	....	16	...	932

[1]Treated on Sept. 21, 1954
[2]Treated on Aug. 4, 1954

Duration of Toxicity

Waters treated with toxaphene may retain toxicity for long periods. Ten Michigan lakes were treated in 1949 and 1950 with Fish-Tox, a fish poison now known to have contained toxaphene. Six remained toxic for more than eight months. One was toxic for 33 months. The amount of toxaphene in this commercial preparation is not known. In 1954 and 1955 the detoxification period of four Michigan lake basins ranged from 2 to 10 months after treatment with toxaphene at a concentration of 0.1 p.p.m. A shallow pond freshened by a flow of spring water detoxified in two months. Shallow lake basins detoxify more rapidly than deep lake basins. Horseshoe Lake has a shallow and a deep basin joined by a narrow connection. After it was treated with toxaphene the shallow basin lost its toxicity three months before the deep basin.

Persistent toxicity may be undesirable from the standpoint of preventing fishing for an extended period, but it has the advantage of assuring a complete kill. Shallow ponds and lakes which detoxify too rapidly when treated with rotenone (Clemens and Martin, 1954) may be successfully treated with toxaphene. A toxicant that can be used after the close of the fishing season that will retain its toxicity through the fall overturn period but detoxify in time for spring or early summer planting would be highly desirable.

In terrestrial soils, microorganisms break down toxaphene and render it non-toxic (Smith and Wenzel, 1947). It is not known whether or not microorganisms of aquatic soils break down this compound. The more rapid detoxification of shallow basins as compared to deep basins suggests that a high ratio of interface surfaces (bottom soil-water and air-water) to water volume favors detoxification.

Detoxification During Laboratory Storage

Water samples containing 0.1 p.p.m. toxaphene were stored in the laboratory in glass containers under a variety of conditions (Table 3). With one exception, all water samples were 30 liters in volume.

The influence of light was investigated by storing samples in an aquarium from which all light was excluded by a covering of black cloth. All other samples were stored under laboratory fluorescent lamps. One water sample was stored in a 55° F. water bath; others were stored at 75° F. One sample had an alkalinity of 6 p.p.m. and the others had an alkalinity of 212 p.p.m. One eight-liter water sample was boiled to reduce the oxygen tension. After cooling, toxaphene was added and samples were stored in sealed glass containers. The oxygen content of this sample was 0.69 p.p.m. as compared to the range of from 6.4 to over 8.0 p.p.m. for other samples. The low oxygen samples were stored for 23 weeks while all others were stored for 12 weeks. To test the influence of water circulation and aeration, one sample was supplied with an air stone delivering a flow of 2 liters of air per minute. A control sample was stored for 12

TABLE 3.—*Effect of storage for a 12-week period under various laboratory conditions upon toxicity of 30-liter water samples containing 0.1 p.p.m. toxaphene*

[10 fish used in each test]

Methyl orange alkalinity (p.p.m.)	Storage conditions				Number of test fish surviving					
					Creek chubs			Bluntnose minnows		
	Temperature (°F.)	Aeration (water circulation)	Dissolved oxygen (p.p.m.)	Light	1 day	2 days	7 days	1 day	2 days	7 days
[1]212 (control)	75	none	6.4—7.0	light	2	0	0	1	1	0
212	75	none	6.4—7.0	light	10	10	9	5	1	1
212	75	air stone	8.0+	light	10	10	8	10	10	5
212	75	none	6.4—7.0	dark	5	1	0	0	0	0
212	55	none	6.4—7.0	light	3	0	0	1	0	0
[2]212	75	none (sealed)	0.69	light	3	2	0	..	..	..
6	75	none	6.4—7.0	light	3	0	0	3	1	0

[1]Control water stored as indicated but toxicant added immediately before testing
[2]8 liters of water stored for 23 weeks

weeks under laboratory conditions of temperature and light. This water was exposed to the air but was not aerated. In the case of the control, the fish toxicant was added after the period of storage.

The potency of samples after storage was tested by recording the survival of minnows after 1, 2, and 7 days of exposure. A chi square test of independence was made between each of the experimental conditions and the control. Survival increased significantly above the control level when the water had a high alkalinity, was stored under normal laboratory conditions of temperature and light, and had abundant oxygen (Table 3). The same results were obtained with bluntnose minnows and creek chubs regardless of whether the water had been aerated or not. Survival of fish in water stored under other combinations of conditions did not differ significantly from that of the control group.

Further tests showed that in the case of un-aerated water stored at room temperature, the toxicity did not change enough to influence the survival of minnows for the first six weeks of storage; i.e., during this period the test fish died about as fast in stored water as they did in the water before storage. After this period, however, survival in the stored water increased steadily.

The increased survival in the aerated water was caused by the water movements rather than by the specific action of the air bubbles on the solution. When a mechanical stirrer was substituted for aeration, 30 liters of water could be detoxified within 48 hours.

Detoxification may be influenced by the water-glass contact area. To test this hypothesis, the bottom of the aquarium was covered with glass marbles. This reduced the time required for detoxification from 168 hours to 24 hours when an air stone was used as a water circulation device. A similar detoxifying influence appeared when gravel was substituted for marbles as a substrate (Table 4). Other substrates such as sand and mud also had a detoxifying effect, although they appeared to be less active as detoxifying agents than gravel or marbles.

TABLE 4.—*Influence of substrate upon rate of detoxification during 24-hour storage period of water samples containing 0.1 p.p.m. toxaphene*

[Water circulation maintained in all aquaria by air stones delivering a flow of 2 liters per minute]

Substrate in aquarium	Bio-assay of stored water with creek chubs			
	Number of tested fish	Percentage survival		
		1 day	2 days	7 days
None (control)	10	20	0	0
Marbles	20	100	90	90
Marbles (sterilized[1])	10	70	30	10
Gravel	10	70	70	70
Gravel (sterilized[2])	10	30	0	0
Sand	10	40	10	0
Mud	10	60	20	10

[1]Aquarium and substrate sterilized with dilute formalin
[2]Aquarium and substrate sterilized with dilute carbolic acid

After a water sample had completely detoxified, the water was siphoned off, and the substrate and the inside surfaces of the aquarium were washed thoroughly with two liters of fresh water. The wash water gave no indication of toxicity when tested with minnows. A toxic material believed to be toxaphene was recovered from the inside of the aquaria and from the marble and gravel substrates by the following procedure: the aquarium and substrate were washed with 50 milliliters of benzene. The benzene was evaporated to dryness in an oven at 60° C., and the residue was treated with three milliliters of isopropyl alcohol. This extract was added to three liters of water, and the potency of the mixture was tested with minnows. Creek chubs were killed by the preparation in four hours. They showed distress reactions characteristic of fish dying from toxaphene poisoning. The fish survived for 7 days in a control sample treated with three milliliters of isopropyl alcohol.

The detoxifying influence of the substrate was inhibited when the substrate of gravel or marbles was removed from the aquarium at 6-hour intervals, sterilized with a dilute solution of either formalin or carbolic acid, washed with distilled water, and returned to the aquarium (Table 4). If this sterilization procedure was stopped, the substrate again became a detoxifying agent within 48 hours. This experiment strongly suggests that detoxification is due to the removal of the chemical by microorganisms. Glass slides suspended in the treated water became populated with a variety of protozoa, rotifers, diatoms, and bacteria within 48 hours.

Use of Toxaphene in Lake Management

Experimental treatments now underway on several lakes will determine whether toxaphene can be used as a fish toxicant without risking prolonged periods of toxicity. To date field trials and laboratory experiments indicate that a concentration of 0.05 p.p.m. of emulsified toxaphene is sufficient for fish eradication. The laboratory tests suggest that somewhat lower concentrations can be used successfully in shallow hard-water lakes having a high range of temperature (70°-80° F.). The detoxifying influence of the substrate that was demonstrated in the laboratory suggests that lakes in which the entire water mass can circulate freely over the bottom sediments are apt to detoxify most rapidly. Conversely, detoxification is likely to proceed slowly or not at all in the hypolimnia of deeper lakes, during summer stagnation. Since the hypolimnion may retain its toxicity longer than the epilimnion, both strata should be tested with live fish before restocking. Survival of test fish in only the epilimnion should not be considered reliable evidence that a lake has detoxified, since upwelling of toxic water from the hypolimnion may make the shallower regions toxic again.

The laboratory results also suggest that for prompt detoxification treatments should be timed to take advantage of natural water movements. Thus, late spring or summer applications should be avoided. Early

fall treatments would make use of the detoxifying influence of the fall overturn.

This chemical appears to be more toxic to fish than to many aquatic invertebrates. Since bottom invertebrates killed by toxaphene reappear in the lake before it loses its toxicity to fish, food organisms are likely to be present by the time the lake is ready for restocking.

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LIFE HISTORIES AND INTER-RELATIONSHIPS OF WALLEYE AND YELLOW PERCH, ESPECIALLY DURING THEIR FIRST SUMMER, IN TWO MINNESOTA LAKES

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Abstract

Shoreline seining of two typical large Minnesota walleye lakes, Mille Lacs and Winnibigoshish, during the summers of 1954 and 1955 showed young-of-year yellow perch and walleye to be closely associated. Throughout the summer the young walleyes were always larger than the young perch. The average length of walleye ranged from about 1.2 inches in late June to 4.8 inches in late August; that of perch growth for the same period ranged from about 0.9 to 2.5 inches. Food studies demonstrated that throughout the summer young perch fed mostly on plankton crustaceans and aquatic insects and young walleyes fed mostly on fish, especially yellow perch. Yearling and older perch taken from the same seining areas fed principally on plankton crustacea and insects during the first part of the summer and shifted somewhat to fish as the season progressed. Considerable numbers of young walleyes and perch were taken from the seining areas in the summer of 1954. Largest catches of young-of-year walleyes in 1954 were made in July when 1,206 per shoreline acre were taken from Mille Lacs and 795 from Winnibigoshish. In 1955, however, similar seining took markedly fewer fish in Mille Lacs Lake and showed a different seasonal distribution of the catch from Lake Winnibigoshish. Possible reasons for these differences are discussed. The close association of young-of-year walleyes and yellow perch along shores together with their differences of growth rate and feeding habits suggest that in typical walleye lakes the size of the perch crop may be an important factor in determining the year-class strength of the associated walleyes.

Introduction

Typical walleye waters in Minnesota are large lakes, usually of more than 1,000 acres. They have cool water, sandy shores, are of moderate fertility and often lack a thermocline in summer. In them the walleye (*Stizostedion v. vitreum*) is the most important sport fish. With it are commonly associated the yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), shallowwater cisco (*Coregonus artedii*), white sucker (*Catostomus c. commersoni*), troutperch (*Percopsis omiscomaycus*), and several kinds of minnows and darters.

During their first summer of life, walleyes and yellow perch of walleye lakes, usually inhabit shallow waters along shores. The present paper is concerned with the life histories of these two percids, especially during their first summer, and with their feeding habits, growth, and inter-relationships. It is during the first summer of life that the initial strength of the walleye year-class is determined. Consequently information on

factors influencing the size of the year-class is of considerable importance in sport-fishing management. Data are presented also on population densities of young walleyes as determined by shoreline seining during the summers of 1954 and 1955 and on feeding habits of yearling and older perch.

Lakes Studied

The present study was conducted on two large walleye lakes; Mille Lacs Lake near Brainerd in central Minnesota, and Lake Winnibigoshish, near Grand Rapids in the north-central part of the state. Both lakes are noted for walleye fishing. Work on the two lakes were carried out separately by the two authors and data combined in the present report.

Description of Mille Lacs Lake.—Mille Lacs Lake is a roughly, rectangular body of water of 131,000 acres. It has a regular and usually sandy shoreline of about 75 miles and a maximum depth of 35 feet. Much of the lake is moderately shallow—30 percent less than 15 feet deep. The extensive gradually sloping beaches are well suited for shoreline seining. The water is hard (total alkalinity, 125 p.p.m.), of moderate chemical fertility, and usually clear and free from algal blooms. There are few submerged weeds along the shores. Because of its wide expanse and heavy wave action, no thermocline is formed in summer. Mille Lacs Lake is near the southern limit of typical Minnesota walleye waters, and water temperatures may rise to 85° F. in midsummer. At such times summer kills of troutperch and cisco often occur.

Mille Lacs Lake drains into the Rum River and thence into the Mississippi. It has only a few small inlet streams suitable for walleye spawning. Most spawning occurs along shores and on reefs in shallow waters, usually between the second week in April and second week in May. If there are heavy storms at spawning time, as in the spring of 1954, windrows of eggs may pile up along the shore. Despite such an egg loss in 1954, however the crop of young walleyes was good. In addition to summer and winter angling for walleyes, Mille Lacs supplies some fishing for northern pike, black crappies (*Pomoxis nigromaculatus*), rock bass (*Ambloplites rupestris*), bluegills (*Lepomis macrochirus*), and largemouth bass (*Micropterus salmoides*). Shoal areas are netted for shallow-water cisco in late fall.

Description of Lake Winnibigoshish.—Lake Winnibigoshish a roughly square-shaped lake has an area of 48,000 acres through which the Mississippi River flows. Its water level which is controlled by a dam fluctuates about 4 feet annually. The shoreline is mostly regular and often sandy. The lake has a maximum depth of about 65 feet and about 40 percent is shallower than 15 feet. It has numerous connected lakes and streams suitable for walleye spawning. Fish from a trap in one of these, Little Cutfoot Sioux Lake, are a source of eggs used for artificial propagation. Natural spawning occurs in adjacent waters and along the shores of Winnibigoshish itself.

The water of Lake Winnibigoshish is hard (total alkalinity, 152.5

p.p.m.) and of moderate fertility. The water is usually clear but light algal blooms occur each summer. No summer thermal stratification occurs but the hypolimnion does not stagnate.

This lake has long been a favorite for walleye fishing. Earlier information on the walleye population and catch has been given by Stoudt and Eddy (1937). In addition to walleye angling, Winnibigoshish supplies good fishing for northern pike, which are taken both by angling and winter spearing, and some fishing for muskellunge, (*Esox masquinongy immaculatus*). The principal non-game species are yellow perch, shallowwater cisco, white suckers, troutperch and minnows, especially *Notropis hudsonius, N. volucellus,* and *N. deliciosus.*

Collection of Fish by Shoreline Seining

To obtain fish for the present study, shoreline seining areas were selected on both lakes where the bottom slopes gradually, and where there were few weeds or other obstructions to seining. These scattered seining areas were chosen to represent different environments and were in places relatively free from human interference. Seining at five such stations was done at 3- or 4-day intervals on Mille Lacs Lake, June 1–September 3, 1954, and at weekly intervals from June 6 to August 29, 1955. On Lake Winnibigoshish seining was done at four stations at 6- or 7-day intervals from June 23 to September 8, 1954, and on the same days from June 24 to August 11, 1955.

In Mille Lacs Lake, during June of both years, a 60- by 6-foot bobbinet seine was used, but no young-of-year perch or walleyes were taken during the month in either year. Starting in the first week of July in Mille Lacs the bobbinet was replaced by a 100- by 6-foot, ¼-inch-mesh bag seine. In Lake Winnibigoshish a 30- by 4-foot, ¼-inch-mesh seine was used throughout the summers of both years.

Seining in Mille Lacs was done by hauling in a seine laid out parallel to and 50 to 200 feet off shore. The approximate area seined was noted each time. All walleyes taken in each haul were counted, and a representative series of walleyes and yellow perch preserved in a formaldehyde solution. Seining in Lake Winnibigoshish was parallel to or at an angle to shore; here for the area seined was noted after each haul. Walleyes retained for study were preserved in a formaldehyde solution. Representative samples of perch (young-of-year, yearlings, and older) were also collected at each station. The numbers of young-of-year perch in Mille Lacs in 1955, exceeded the young-of-year walleyes on every seining day. Over the seining period the advantage was 35 to 1. Total area seined on the seining dates ranged from 0.38 acre to 1.03 acres in Winnibigoshish, and 0.14 acre to 2.18 acres in Mille Lacs.

1954 seining data.—In 1954 young-of-year walleyes were taken from Lake Winnibigoshish beginning June 23 and thereafter at each seining until September 9. In Mille Lacs young walleyes were not taken until July 16, but after that date they were collected at each seining. Seasonal

changes in the catch were similar in the two lakes in 1954—a rapid rise in numbers taken per unit area to a peak in July, followed by a sharp decline and a tapering off at a lower level of abundance late in the summer (Fig. 1). Highest numbers were taken on July 13 in Winnibigoshish and July 26 in Mille Lacs. On these dates the respective population density was estimated to be 795 and 1,206 young-of-year walleyes per shoreline acre.

Catches differed greatly among seining stations on any seining day, and

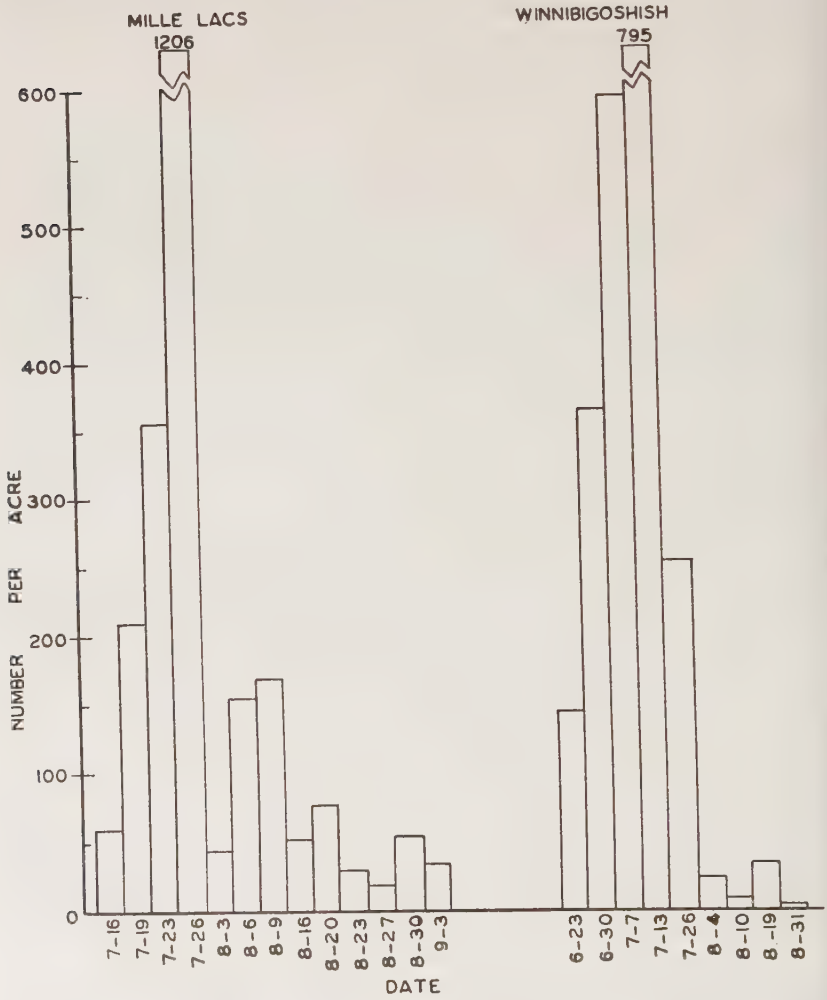

FIGURE 1.—Average number of young-of-year walleyes per acre taken by shoreline seining from two Minnesota lakes throughout the summer of 1954.

the pattern of variation was not consistent from one seining to the next. At Mille Lacs it appeared that afternoon hauls regularly took more young walleyes than did morning hauls. Of the 65 hauls made on this lake, 23 took fish at the rate of 100 or more per acre, and of these more productive hauls, 21 were made between noon and 5:15 p.m. In Winnibigoshish no relationship was noted between seine-haul catches and time of day or water conditions.

The reason for differences in average population density along the shores at different times during the summer is not known, but they appear to be related at least in part to movement of fish in and out of the shallows along the shores. It is possible also that as the season progressed the increased strength and mobility of young-of-year walleyes made it easier for them to escape the seine. In Mille Lacs no very small walleyes were taken by bobbinet seining in June; yet larger walleyes were abundant in July. The rapid decline of population density after the peak was reached in July seems too great to be accounted for by mortality alone. Migration of the larger young-of-year walleyes into deeper water appears more likely. This supposition is supported by the apparently erratic growth of the fish at the end of the season (Figs. 2 and 3).

1955 seining data.—Shoreline seining of both lakes in 1955, carried out along the same plan as in 1954, revealed large differences between years in the numbers of young-of-year walleyes and in the seasonal change of the catch.

In Mille Lacs Lake the catch of young-of-year walleyes was markedly lower in 1955 than in 1954. The maximum take was 11 per shoreline area in 1955 as contrasted to 1,206 the preceding year. Two explanations are suggested: fewer young-of-year walleyes were produced in 1955; or higher water temperatures caused these fish to seek deeper and cooler water where they were not available to the seine. In 1954 water temperatures on the seining areas were below 75° F., but in 1955 were often above 80° F. Similar observations on two large walleye rearing ponds near the lake showed water temperatures about 5° higher in 1955 than in 1954. Average of maximum air temperatures for July at Brainerd, the nearest weather station, was 2.9° higher in 1955 than in 1954.

It should be noted, however, that predation may have had a greater effect on the young-of-year walleyes in Mille Lacs in 1955 than in 1954. More yearling walleyes and yearling perch were taken in the seine hauls in 1950 than in 1954.

In Lake Winnibigoshish, young-of-year walleyes appear to have been about equally abundant in both years. The highest catches were 692 per shoreline acre in 1955 and 795 in 1954. The seasonal changes in the catch differed, however, in the two years. In 1954, the catch was highest in mid-July and the catch curve had an inverted S-shape. In 1955 the highest catches were in late June and August and the catch curve had a reversed J-shape.

The average maximum air temperature at Leech Lake Dam near Lake Winnibigoshish was higher in July 1955 than in July 1954, (83.3° F.

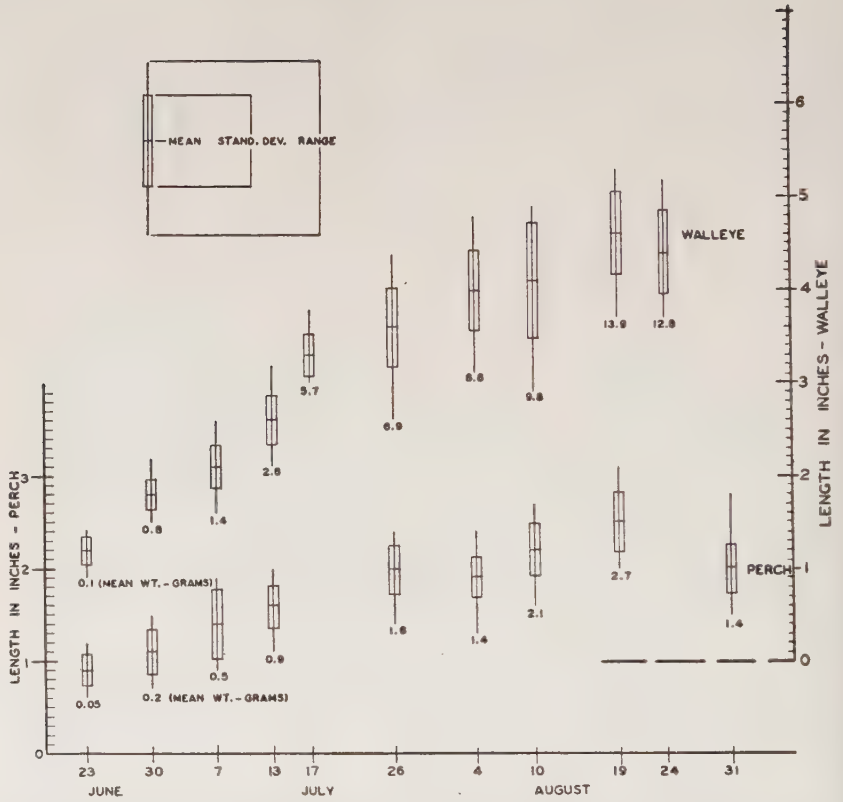

FIGURE 2.—Growth in length and weight of young-of-year yellow perch and walleyes in Lake Winnibigoshish, Minnesota, during the summer of 1954.

as opposed to 79.5° F.) and water temperatures from four large fish rearing ponds in the vicinity were about 5° F. higher in July 1955 than in July 1954. In the ponds young-of-year walleyes moved into deeper waters at the time of high water temperatures of July 1955. A similar movement may well have influenced the catch along the shore of Lake Winnibigoshish.

GROWTH OF YOUNG-OF-YEAR WALLEYES AND PERCH

Growth of young-of-year walleyes.—The graph of the growth in length and weight of young-of-year walleyes during the summer of 1954 (Fig. 2 and 3) includes ranges and standard deviations of the means. The number of measurements represented by individual means varies from 6 to 318. In all, 229 fish were measured from Winnibigoshish and 1,898 fish from Mille Lacs.

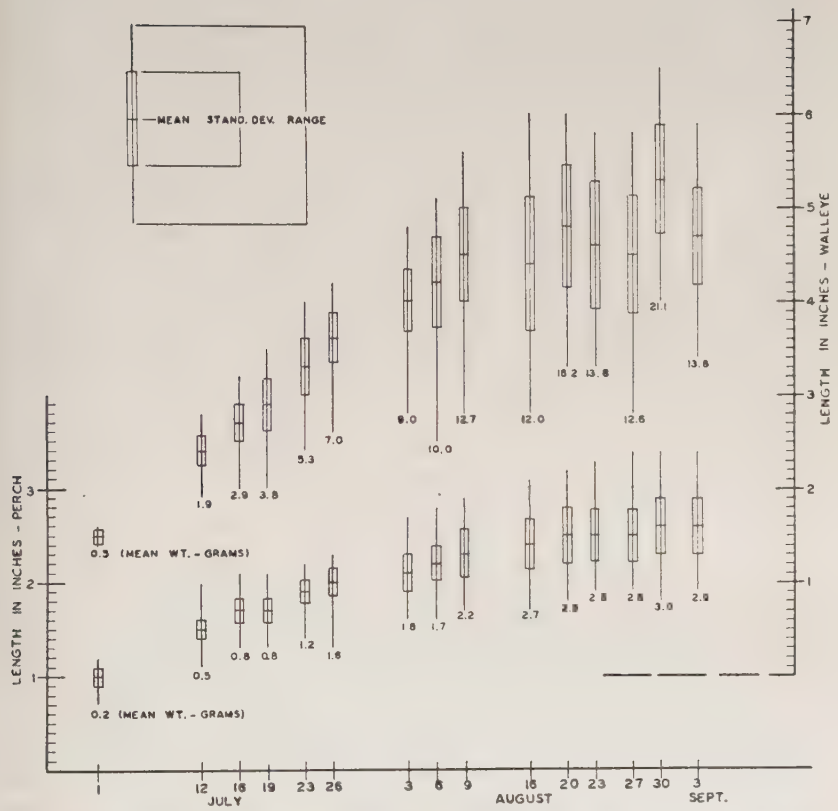

FIGURE 3.—Growth in length and weight of young-of-year yellow perch and walleyes in Lake Mille Lacs, Minnesota, during the summer of 1954.

In Lake Winnibigoshish the walleyes of the first sample, taken June 23, averaged 1.2 inches in total length. The average length was 4.6 inches on August 19. Average weight during this same period increased from 0.1 to 13.9 grams. In Mille Lacs the average length increased from 1.5 inches on July 1 to 4.8 inches on August 20 and average weight during the same period rose from 0.5 to 16.2 grams. In both lakes, growth apparently was irregular toward the end of the season, suggesting that fish were moving in and out of the area, and that the samples were not representative.

Growth of young-of-year yellow perch.—With the yellow perch as with the walleyes, the graphical representation of the growth of young-of-year fish during the summer of 1954 in (Figs. 2 and 3) includes ranges and standard deviation.

In Lake Winnibigoshish the average length of young perch increased from 0.9 inch on June 23 to 2.2 inches on August 10 and average weight

during the same period rose from 0.05 to 2.1 grams. The figure for August 31 showing an apparent decline in mean total length probably reflects sampling errors in the seine catches.

Growth of yellow perch was similar in Mille Lacs—from 1.0 inch on July 1 to 2.5 inches on August 20 and 3.0 inches on September 3. On these same dates, the average weights were 0.2, 2.9 and 2.9 grams.

Yellow perch usually spawn about 2 weeks later than walleyes in these waters and in a different habitat—usually in protected weedy areas.

Growth trends.—Growth in length of both young-of-year walleyes and yellow perch appeared to be curvilinear. Maximum increase of length occurred during July, the first month of the study period. In contrast, mean weight increased almost linearly throughout the summer. It appears that increase in length of young-of-year walleye and perch slows down in midsummer but that weight increases at a nearly constant rate throughout the summer. Throughout the summer of 1954, young-of-year perch were consistently smaller than the young-of-year walleyes inhabiting the same shoreline areas, and most of the perch young-of-year were of sizes that could be eaten by young-of-year walleyes. The same size relationship existed in 1955.

Food of Walleyes and Yellow Perch

Stomach contents of preserved fish were later examined with the aid of a binocular microscope. Volume of food was measured by water displacement. The data for 1954 are expressed as percentage composition of total volume (Figs. 4 and 5). Only stomachs containing food were used in the analysis. In all, 742 stomachs from young-of-year walleyes were examined from Mille Lacs Lake and 355 from Lake Winnibigoshish. From these same lakes, 1,264 and 415 yellow perch stomachs were studied. For purposes of graphic presentation, the food in the stomachs has been grouped in four categories: fish; plankton crustacea; insects; and other food.

Food of young-of-year walleyes.—The food of the young-of-year walleyes of Lake Winnibigoshish was almost entirely fish (Fig. 4). Items such as plankton crustacea and insects made up less than 1 percent of the food. Insects occurred mostly in the stomachs of fish taken on three seining dates in August and were mostly dipterous larvae. Of fish remains in the stomachs, 52 percent was identifiable as young-of-year perch. Identifiable yellow perch made up from 13 to 68 percent of the total food volume on individual seining dates. With the exception of a few minnows (*Notropis* spp.) the rest of the fish remains could not be identified. It is likely, however, that much of the unidentifiable fish was perch.

The stomach contents of walleyes from Mille Lacs Lake were similar. Over the entire summer 98.9 percent of the volume of food was fish. On individual seining dates 43 to 95 percent of the food was identifiable as yellow perch and during the entire seining period perch constituted 77 percent of the diet. Only two other kinds of fish were at all common in

the stomachs—the spottail shiner (*Notropis hudsonius*) and the johnny darter (*Boleosoma nigrum*). These species made up 3 and 4 percent, respectively of the total stomach contents. Mimic shiners (*Notropis volucellus*), troutperch (*Percopsis omiscomaycus*), and the brook stickelback (*Eucalia inconstans*) were also found. Fourteen percent of the food

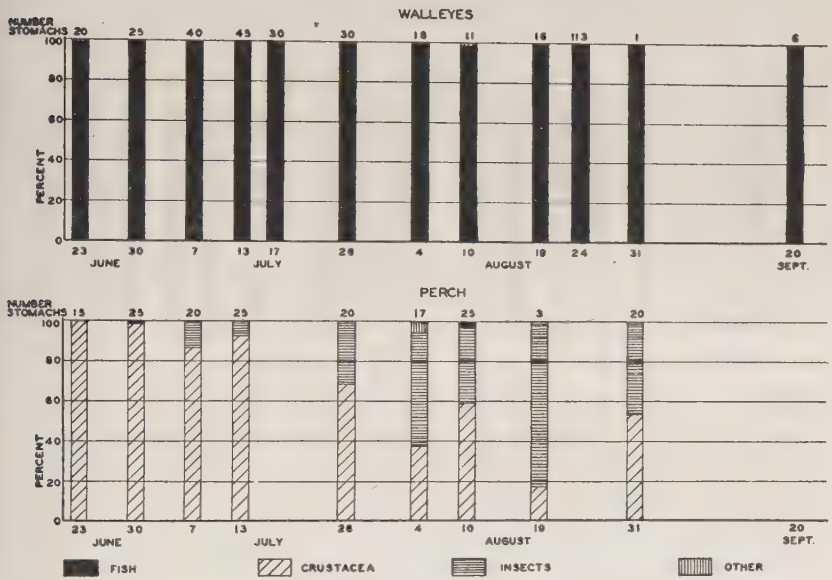

FIGURE 4.—Percentage composition of food, by volume of young-of-year yellow perch and walleyes in Lake Winnibigoshish, Minnesota, summer of 1954.

volume was of unidentifiable fish remains. Insects, which made up 1 percent of the total food volume, were mostly chironomids, odonates, and ephemerids.

The food of young-of-year walleyes in these lakes was similar to that found by Eschmeyer (1950) in Lake Gogebic, Michigan. He reported fish to make up 88 percent of the food, plankton crustaceans, 10.3 percent, and insects, 1.7 percent. He estimated yellow perch to make up 68 percent of all the food.

The walleyes of the present series were not taken until they were between 1.0 and 1.5 inches long. Smith and Moyle (1945) showed that, in natural ponds in which walleye fry had been stocked, the fry began feeding on rotifers, copepods, and cladocerans, then shifted to an insect-crustacean diet, and finally to fish.

Food of young-of-year yellow perch.—In Lake Winnibigoshish plankton crustaceans made up the bulk of the food of young-of-year perch during June and July. Insects became increasingly important as the season

advanced. Fish and "other" foods were taken only in inconsequential amounts. During July plankton crustaceans made up 79 percent of the food volume and insects the remaining 21 percent. Fish were found in the stomachs in small amounts only on July 13 and August 10. In stomachs of 170 young-of-year perch taken during the summer of 1954, 62 percent of the volume of food was of plankton crustaceans, 37 percent of insects, 0.2 percent of fish, and 0.8 percent of other items. Crustacea

FIGURE 5.—Percentage composition of food, by volume, of young-of-year yellow perch and walleyes in Mille Lacs Lake, Minnesota, during summer of 1954.

from young perch were primarily *Bosmina, Daphnia,* and *Hyalella.* Insects were mostly immature dipterans, odonates, and ephemerids.

Food of young yellow perch from Mille Lacs was similar. In July plankton crustaceans predominated in the diet. Insects became increasingly important later in the summer. Again fish were of minor importance. Over the entire summer, crustaceans made up 72 percent of the total volume of the food, insects were 26 percent, fish were 1.5 percent, and other foods 0.5 percent. The crustaceans were principally *Diaptomus, Hyalella,* and cladocerans. Insects were mostly chironomids, odonates, and ephemerids. Leeches were eaten occasionally. Analysis of 61 perch stom-

achs taken in 1955 in Mille Lacs Lake showed similar percentages of food items.

Food of yearling and older yellow perch.—Of 90 yearling perch collected from Mille Lacs Lake in 1954, 74 had stomachs containing food. The food in the stomachs consisted of 43 percent insects, 32 percent fish, 24 percent crustaceans, and 1 percent other items. Crustacea identified from the stomachs were *Hyalella,* cladocerans, and a few crayfish. Much of the fish remains in the stomachs was unidentifiable. Certain identification was made of one perch and one burbot (*Lota maculosa*).

Diet of yearling perch in 1955, as determined from 750 stomachs, was principally of aquatic insects, and crustaceans (*Hyalella* and cladocerans). On only two seining days were fish present in the stomachs and then in very small amounts. The identifiable fish were perch and spottail shiners. The food, in general, resembled the food of younger perch, except that larger items were preferred.

In all, 245 stomachs of yearling and older yellow perch from Lake Winnibigoshish were examined in 1954. Crustacea and insects were the principal foods in late June (51 and 41 percent of the food volume). The diet during early July was similar to that in June but by late July crustaceans were replaced by fish as a major food item. Most of the fish remains were not identifiable. For example, on July 26 when 93 percent of the food was fish, only 26 percent could be identified as perch and 2 percent as centrarchids. For the entire season the composition of the diet of the older perch was; crustaceans, 24 percent; insects, 40 percent; fish, 33 percent; and other foods, 3 percent. Crustacea eaten were primarily *Daphnia* and *Hyalella* and insects were mostly odonates, ephemerids, and dipterous larve. Crayfish perdominated among other foods.

Summary of food habits of walleye and yellow perch.—Young-of-year walleyes for the period from July to September were primarily fish-eaters and fed principally on young perch. Young-of-year perch fed mostly on crustaceans and insects. The older perch fed mostly on crustaceans and insects in the first part of the season and ate some fish during the last part of the summer. There was no evidence of serious competition for food between the yellow perch of the sizes studied and young-of-year walleyes. The association of these two species during their first summer appears to represent a natural food chain—the perch feed primarily on invertebrates and the walleyes principally on the perch.

Relationships Between Walleyes and Yellow Perch

It has long been known that in typical Minnesota walleye lakes populations of walleyes are usually associated with fairly large populations of yellow perch. Recently, Smith and Krefting (1953) noted a remarkably close correlation between the six year classes of walleye and perch in the Red Lakes, northern Minnesota. Gill-net catches also show this same

relationship for Lake Winnibigoshish. It appears that good perch years are usually good walleye years in such lakes.

The present study suggests that the similar habitat preference of young-of-year perch and walleyes together with their differences in growth and feeding habits may be an important factor in this relationship. It also points out the necessity for understanding and managing whole fish populations rather than placing emphasis on a single desirable species. The yellow perch, although legally a rough fish in Minnesota and little fished, seems to be an important member of the fish society of walleye waters.

Acknowledgments

Dr. John B. Moyle gave assistance and advice in planning this investigation and in preparing the manuscript and Mr. Edward J. Longtin drafted the figures; both are staff members of the Fisheries Research Unit, Bureau of Fisheries, Minnesota Department of Conservation.

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TEMPERATURE TOLERANCE OF EGGS AND YOUNG OF COLUMBIA RIVER CHINOOK SALMON[1]

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Abstract

A study was made on the temperature tolerance of eggs and young of chinook salmon which spawn in the main stem of the Columbia River. The control temperature followed a seasonal trend typical for the locality. It started at 57°F., reached a minimum of 36°F., and increased to 47°F. at the end of the test. Other experimental lots averaged about 4°F. colder and 2°F., 4°F., and 8°F. warmer than the control throughout the greater part of the test.

Significant mortality above that of the control occurred only in the warmest lot. Although about 90 percent of the eggs in this group hatched successfully, the fry and early fingerlings suffered heavy mortalities even though the mean temperature of this lot was well below 50°F. during the fingerling stage.

The results of this single experiment indicated that the eggs could begin incubation at temperatures as high as 61°F. without significant loss.

Introduction

The limited distribution of chinook salmon, *Oncorhynchus tschawytscha* (Walbaum) is an indication of the requirement of this species for relatively cool water. Observed water temperatures during the spawning period do, however, cover a rather wide range. Burner (1951) found spawning within a range of 42° F. to 58° F. in the Toutle River in Washington. Mattson (1948) found the temperature to range from 43° F. to 64.5° F. during the spawning period in the Willamette River in Oregon.

One race of fall chinook salmon spawns in the main stem of the Columbia River near Priest Rapids in south-central Washington, between the middle of October and the middle of November. The temperature, when spawning activity has been observed, has ranged from 50° F. to 62° F. with an average diurnal range approaching 1.5° F. The following study was conducted to help determine the maximum temperature, following a seasonal pattern, that could be tolerated by this race of chinook salmon.

Methods

A pair of ripe chinook salmon were captured on spawning grounds just below Priest Rapids on October 26, 1953. Approximately 5,800 eggs were

[1] This report is based on work performed for the Atomic Energy Commission by the General Electric Company under Contract No. W-31-109-Eng-52.

taken and fertilized in the field. The eggs were transported immediately to the Aquatic Biology laboratory, within the Hanford project, and distributed among five enameled steel troughs each 5 feet in length and containing approximately 19 gallons of water. A flow of 2 gallons per minute of Columbia River water was furnished each trough.

The temperature of the control was adjusted to follow a seasonal trend typical for the Priest Rapids section and was the average for the years 1946–1952. The temperature of the coldest lot was arbitrarily set at 3.6° F. (2° C.) below the control. The other experimental lots averaged on the order of 2° F., 4° F., and 8° F. above the control throughout the greater part of the test so that the study was made over a reasonable temperature spread. Freon refrigeration units of $7\frac{1}{2}$ ton capacity were used for cooling. Electrical immersion elements of 2,000 watt capacity heated the water. Temperature adjustments were made in the supply system before the water entered the troughs. Figure 1 shows the average daily temperatures, calculated by using hourly averages, for each of the conditions.

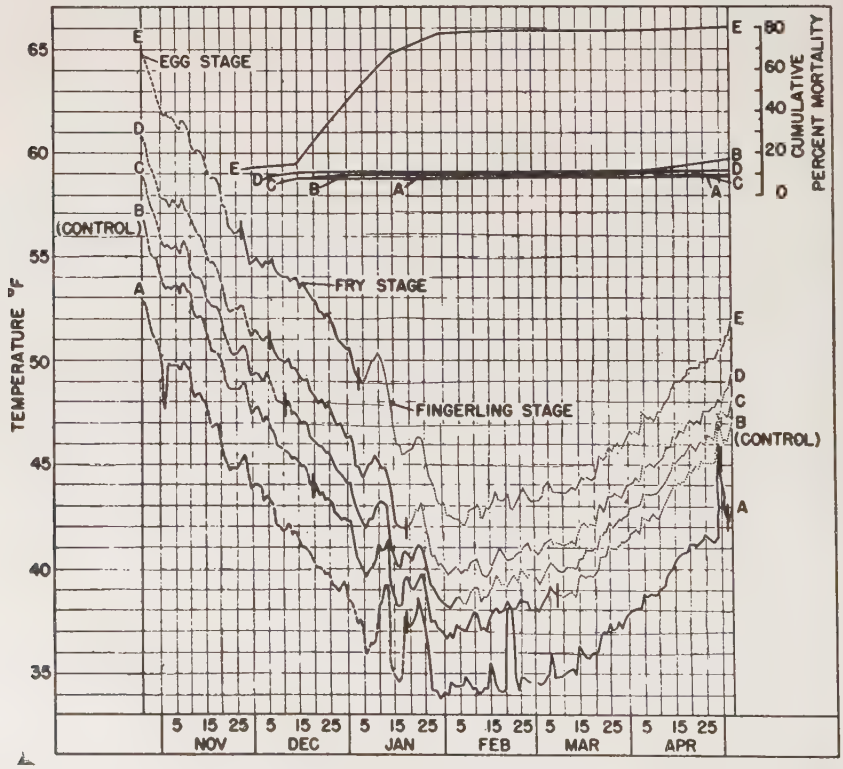

FIGURE 1.—Daily average temperatures and resulting cumulative mortalities plotted at semimonthly intervals after hatching.

The mechanics of the temperature control were carried out in the following manner. Desired temperatures were drawn on charts placed on temperature recorders monitoring the troughs. The water was then cooled or heated as necessary so that the recording pens of the instruments retraced the plotted lines.

Throughout the experiment the actual temperatures averaged within 0.2° F. of the experimental temperatures sought. Only 6 percent of the daily averages showed departures as great as 0.5° F. from the desired temperatures sought. These were practically all confined to the coldest lot and resulted from refrigeration trouble. The temperature recorders were calibrated routinely to the nearest 0.2° F. with a thermometer tested by the National Bureau of Standards.

The eggs and resulting fish were given normal fish-cultural care. Daily records of mortality were maintained. During the egg stage, dead eggs were examined to determine the stage of development reached. They were cleared in salt solution and fixed with acetic acid so that embryo formation might be observed. After feeding started, samples from each lot were weighed at 2-week intervals. As the fish increased in size, it was necessary to reduce the numbers held in each trough to prevent overcrowding. Thus, while the numbers in each lot during the egg, fry, and early fingerling stages were generally in the 800 to 900 range, the greater part of the fingerling study was based on a reduced sample of 100.

The experiment was terminated on May 5, 1954.

Results and Discussion

Mortalities are summarized in Table 1.

The temperature patterns followed for Lots A, C, and D did not cause mortalities which differed significantly from the control (Lot B). In the

Table 1.—*Mortalities of young chinook salmon exposed to different temperature conditions*

Lot	Initial temperature	Percentage mortality			
		Eggs	Fry[1]	Fingerlings[2]	Total[3]
A	52.9	6.4	1.5	0.0	7.8
B (control)	56.9	7.9	2.0	7.0	16.1
C	59.0	6.2	1.1	3.0	10.1
D	60.9	8.7	1.8	0.0	10.4
E	65.2	10.8	45.9	56.4	79.0

[1]Fry stage is from hatching to start of feeding
[2]Owing to different developmental rates, the fingerling stage varied from one day in Lot A to 17 weeks in Lot E
[3]Total mortality is based on original number of eggs; egg, fry, and fingerling mortalities are not additive

highest temperature (Lot E) mortality was significantly greater (5 percent level of probability) among the eggs, fry, and fingerlings.

The dead eggs were divided into four stages. Stage 1 included infertile eggs and eggs in which embryo development was not definite. Stage 2 in-

cluded developing embryos which had not reached the eyed stage. In Stage 3 the eggs were eyed, but the length of the embryo was less than half the egg circumference. Stage 4 designates embryos whose length is equal to or greater than half of the egg circumference. Figure 2 shows the percentage mortality in each stage. The mortality which occurred during the younger developmental stages, i.e., 1, 2 and even 3, appears to be of a random nature and shows no correlation with temperature. However, in the warmest lot, E, there was a marked increase in mortality during the last stage of development.

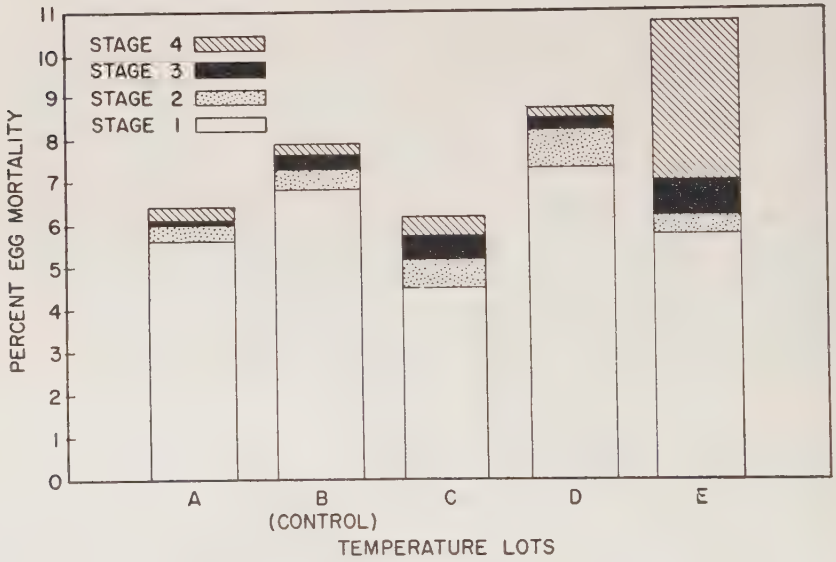

FIGURE 2.—Developmental stages reached by eggs at time of mortality.

The upper portion of Figure 1 shows the cumulative mortality after hatching, plotted at semimonthly intervals. The mortality was low (8 to 16 percent) and similar in Lots A through D. Much greater mortality (79 percent) occurred in Lot E, and most of this occurred during the last half of the fry stage and soon after feeding began. During this period of heavy mortality the temperature ranged from 54° F. to 43° F. and should not have been unfavorable. This mortality pattern gives strong indication of early embryological damage which was not manifested until a later stage of development. Johnson and Brice (1953) found that chinook salmon eggs incubated in Dorena Reservoir water at temperatures over 60° F. suffered excessive mortality, and the adverse effects of these high water temperatures continued to be reflected in the mortality data through the fry and early fingerling stages.

Growth results are summarized in Table 2. The warmer temperatures favored growth.

TABLE 2.—*Growth of young chinook salmon exposed to different temperature conditions*

Lot	Days to feeding	Average weight at start of feeding (grams)	Average weight at conclusion (grams)
A	189	0.5	0.5
B (control)	133	0.6	1.0
C	102	0.6	1.3
D	85	0.6	2.2
E	70	0.5	4.1

ACKNOWLEDGMENTS

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THE PRODUCTION AND MANAGEMENT OF ALABAMA'S STATE-OWNED PUBLIC FISHING LAKES

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Abstract

The construction of lakes by the State Department of Conservation was initiated to provide fishing in those areas having insufficient fishing waters. The lakes were constructed on carefully selected sites so that they could be managed for maximum fish production. Efforts were made to eliminate all native fish from the streams, ponds, and pot-holes within the entire watershed in addition to those in the lake area prior to stocking with bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), and largemouth bass (*Micropterus salmoides*). To keep these lakes in balance and producing high annual yields of fish, it was necessary to employ various management techniques, including fertilization, fish-population control, corrective restocking, and control of aquatic weeds and algae.

Alabama has 11 managed lakes containing a total of 591 acres that have been open to public fishing for 2 to 5 years. Three of the lakes, totalling 155 acres, have been opened for 5 years, 3 containing 163 acres for 4 years, 1 with 40 acres for 3 years, and 4 containing 233 acres for 2 years. During the time that these lakes have been opened, they have provided a total of 379,460 fisherman-trips in which the anglers caught a total of 1,291,012 fish weighing 364,062 pounds. These lakes, therefore, provided an annual average of 189 fisherman-trips per acre and an annual average catch of 642 fish weighing 180.9 pounds per acre. Although the lakes were subjected to extremely heavy fishing pressure, the average catch per fisherman-trip was 3.4 fish weighing 0.96 pound.

Introduction

Alabama's program of state-owned and managed public fishing lakes originated in 1948 with the construction of 3 lakes with areas of 42, 53, and 60 acres. Since that time additional lakes have been constructed as funds became available. Eleven of these lakes, ranging in size from 32 to 80 acres, have been opened to public fishing for 2 to 5 years. The objective of the program was to create good fishing waters in localities which were extremely deficient in fishing areas. The sites were carefully studied and only those suitable for the construction of lakes that could be fertilized and otherwise managed to obtain high fish production were selected. The lakes were stocked with a combination of bluegill, redear sunfish, and largemouth bass at rates recommended by Swingle (1949, 1951, 1952) for fertilized ponds in the Southeast. All lakes were checked periodically for balance by the method described by Swingle (1945). Various management techniques such as marginal poisoning, sectional poisoning, trapping, and corrective restocking were utilized in some of the lakes to keep them in balance.

Once the lakes were opened to fishing, they remained open from daylight to dark every day in the year. Daily records of the number of fishermen and the numbers, weights, and species of all fish caught were kept by lake managers who usually lived at the lakes.

The lake areas were considered as minor state parks and although the lakes were built primarily for fishing, they actually provided multipurpose recreational areas. Thousands of people in addition to fishermen visited the lakes annually for swimming, picnicking, and boating.

Selection of Sites and Construction of Lakes

In general, the sites of the lakes were selected because they possessed the essential characteristics as described by Lawrence (1949) for Alabama. Care was taken to select sites and construct lakes only in those areas that had inadequate fishing areas (Byrd and Moss, 1951). Furthermore, the final selection of sites by departmental engineers and biologists was based on the general accessibility to the public, suitability of the ratio of watershed to lake area, and freedom from the effects of erosion. The ratio of watershed to lake area ranged from 6:1 in the "black-belt" soils to 18:1 in the coastal plains. The average of the ratios for all the lakes was about 12:1. Approximately 95 percent of the watershed areas of these lakes were in woodlands or improved pastures and therefore relatively free from erosion. All lands on which these lakes were constructed and frequently the entire watersheds were purchased by various county sportsmen or civic groups and subsequently deeded to the State Conservation Department without charge.

The lakes, designed by departmental engineers, were constructed by contract. All dams were earthen, complete with drain valves and concrete spillways. The dams were constructed in areas where an adequate quantity of good clay was available and were designed to have a 3:1 slope on the lakeside and a 2.5:1 slope on the other. Usually the edges of the lakes were deepened to a minimum of 18 to 24 inches and the sites were cleared of brush and trees.

Stocking Methods

The 11 lakes were stocked with 1,000 to 1,500 bluegill and redear sunfish fingerlings (approximately 85 percent bluegill and 15 percent redear sunfish) and 100 to 125 largemouth bass fingerlings per acre. The indicated ratios are the range of those recommended by Swingle (1949, 1951, and 1952). These particular species and stocking ratios were employed for fertilized ponds in the Southeast to establish fish populations that would provide successive annual crops of harvestable fish. Populations meeting this requirement were described by Swingle (1950) as "balanced." The lakes were stocked with bluegill and redear sunfish during the fall or winter usually in October or November and with largemouth bass the following spring in April or May. Efforts were made to eradicate native fish by treating all waters in the lake areas with approximately

5 p.p.m. rotenone at the time the lakes were impounded in the fall and prior to the stocking of bluegill, redear sunfish, and largemouth bass. Several species of fish, however, either survived the rotenone treatments or swam up the spillways into some of the lakes. The yellow bullhead (*Ameriurus natalis*), and speckled bullhead (*Ameriurus nebulosus marmoratus*), were able to establish themselves in most of the lakes. Other species that appeared in some of these lakes in significant numbers were as follows: redeye bass (*Micropterus coosae*); warmouth (*Chaenobryttus coronarius*); green sunfish (*Lepomis cyanellus*); longear sunfish (*Lepomis megalotis*); spotted sunfish (*Lepomis punctatus*); and golden shiner (*Notemigonus crysoleucas*).

Production of Fish from the Lakes

The 11 state-owned lakes were first opened to fishing in June or July of the year following stocking. The opening, therefore, was about 18 to 19 months after the bluegill and redear sunfish were stocked and approximately 13 to 14 months after the largemouth bass were planted. Once the lakes were opened to fishing, they remained open from daylight to dark every day in the year. The usual creel limit was 20 bluegill or redear sunfish and 6 largemouth bass per fisherman-trip; no size limits were imposed.

All of the 11 lakes, containing a total of 591 acres have been open to fishing for at least 2 years. Three lakes, totalling 155 acres, have been opened for 5 years, 3 containing 163 acres for 4 years, 1 with 40 acres for 3 years, and 4 containing 233 acres for 2 years. During the time that these lakes have been open, they have provided a total of 379,460 fisherman-trips in which the anglers caught a total of 1,291,012 fish weighing 364,062 pounds.

The average annual number of fisherman-trips per acre on the 11 lakes was 189 and the average annual catch per acre was 642 fish weighing 180.9 pounds (Table 1). The average annual number of fisherman-trips per acre for each lake ranged from 102 in Lamar Lake to 282 in Cullman Lake and the average annual catch of all species per acre ranged from 126.0 pounds in Cullman Lake to 228.5 pounds in Pike Lake. Although the fishing pressure on these lakes was heavy, the average catch per fisherman-trip was 3.4 fish weighing 0.96 pound. The fish catches from these lakes compared favorably with those reported from experimental ponds by Swingle (1945, 1952).

The average annual combined catch of bluegill and redear sunfish per acre from all lakes was 144 pounds (range from 88.7 pounds in Pike Lake to 196.7 pounds in Crenshaw Lake). The average annual catch of largemouth bass per acre from the 11 lakes was 27.6 pounds (range from 10.3 pounds in Lamar Lake to 51.8 pounds in Clay Lake). The average annual catch of bullheads was low in most of the lakes. In three lakes—Barbour, Clay, and Marengo—the average annual catch of bullheads was less than 0.06 pound per acre and in 6 other lakes it was less than 8 pounds per

TABLE 1.—*Summary of the average number of fisherman-trips and average annual catch of fish per acre from state-owned fishing lakes open to public fishing for 2 to 5 years*

Name of lake	Area (acres)	Number of years open to fishing	Average annual number of fisherman-trips per acre	Average annual catch per acre							
				Sunfish[1]		Largemouth bass		Bullhead		Total	
				Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
Barbour	75	2	176	958	177.2	13	12.1	...[2]	....[2]	971	189.3
Butler	42	5	192	374	119.4	47	40.3	5	4.3	426	164.0
Clay	51	4	278	382	133.5	53	51.8	...	...	435	185.3
Coffee	80	4	190	780	175.8	28	29.1	10	6.3	818	211.2
Crenshaw	53	5	188	969	196.7	10	14.9	3	3.1	982	214.7
Cullman	32	4	282	553	106.3	13	15.9	16	3.8	582	126.0
Fayette	60	5	172	408	135.9	43	29.9	8	5.0	459	170.8
Lamar	68	2	102	460	106.9	13	10.3	123	26.5	596	143.7
Marengo	40	3	109	471	144.8	29	22.5	...[2]	....[2]	500	167.3
Marion	45	2	163	362	92.7	28	26.3	17	7.9	407	126.9
Pike	45	2	177	416	88.7	59	43.9	139	95.9	614	228.5
Average	53.7	3.5	189	591	144.0	31	27.6	20	9.3	642	180.9

[1]Bluegill and redear sunfish
[2]Less than 0.06

acre. Lamar and Pike Lakes, however, had an average annual catch of 26.5 and 95.9 pounds of bullheads per acre, respectively.

The average annual catch of largemouth bass per acre from these 11 lakes containing 591 acres compared favorably with those from an 18-acre experimental lake managed primarily for bass production (Bennett, 1950, 1954). The largest bass catches per acre were recorded from lakes which did not require any fish-population control measures or restocking although the lakes were heavily fished for several years. For example, Clay and Butler Lakes had average annual catches of 51.8 and 40.3 pounds of largemouth bass per acre, respectively, although they were fished continuously for 4 and 5 years. Also, Fayette Lake, which was opened to fishing for 5 consecutive years and did not require fish-population control measures or restocking, had an average annual catch of 29.9 pounds of bass per acre.

The average number of fisherman-trips and the average catch of fish per acre remained relatively stable for each of the 5 years that the lakes were open for fishing (Table 2). In the first year the average number of fisherman-trips per acre was 207 and the fishermen caught 758 fish weighing 199.8 pounds and in the fifth year there were 199 fisherman-trips and an average catch of 706 fish weighing 213.4 pounds. Bullheads showed the greatest variability in catch. The take was 48 bullheads weighing 16.5 pounds per acre during the first year but only 2 bullheads weighing 1.9 pounds per acre were caught during the fifth year. The average combined catch of bluegill and redear sunfish was greater during the fifth year than in the first year. The average catch per acre for the first year was 671 bluegill and redear sunfish weighing 154.9 pounds whereas the average catch per acre for the fifth year was 672 bluegill and redear sunfish weighing 176.7 pounds. The average catch per acre of largemouth bass the first year was 39 bass weighing 28.4 pounds while for the fifth year the average catch was 32 bass weighing 34.8 pounds.

Management of the Lakes

Control of the fish population offered the major problem in the management of the lakes. The populations in five lakes (Butler, Clay, Fayette, Marengo, and Pike) remained in balance and hence did not require any control measures or restocking during the entire time that they were open to fishing. Five lakes (Barbour, Coffee, Crenshaw, Cullman, and Lamar) developed unbalanced fish populations after various periods of time. One lake (Marion) was severely damaged by silt deposits which resulted from a newly constructed highway within the drainage area and had to be drained and renovated after the second year of fishing. Although it was necessary to use various management techniques to keep some of these lakes in balance, the average fish catch remained relatively high each year in all of them.

Several factors probably contributed to the unbalanced condition of the fish populations in certain of the lakes. For example, Crenshaw and Cull-

TABLE 2.—*Average number of fisherman-trips and average catch of fish per acre for each of the 5 years that state-owned public fishing lakes have been open for public fishing*

Year after opening of lakes	Number of lakes	Area (acres)	Average number of fisherman-trips per acre	Average catch per acre							
				Sunfish[1]		Largemouth bass		Bullhead		Total	
				Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
First	11	591	207	671	154.9	39	28.4	48	16.5	758	199.8
Second	11	591	173	577	139.9	24	20.7	16	11.2	617	171.8
Third	7	358	170	448	118.2	27	27.7	3	2.7	478	148.6
Fourth	6	318	199	588	144.3	31	35.1	4	3.2	623	182.6
Fifth	3	155	199	672	176.7	32	34.8	2	1.9	706	213.4

[1]Bluegill and redear sunfish

man Lakes suffered heavy fish kills that apparently were caused by dissolved-oxygen deficiencies or some unknown fish disease or diseases. The loss of a large weight of harvestable-size fish resulted in an overcrowded bluegill population. Coffee Lake was in balance for the first and second years when 260 and 311 pounds of fish were harvested per acre. During the latter part of the second open year, however, large numbers of adult fish were lost from Coffee Lake when heavy rains caused flood waters to pass over the regular and emergency spillways at a depth of 2 to 3 feet. This loss in addition to the heavy catch, apparently reduced the adult population below the requirements for balance (Swingle, 1950) and overpopulation of bluegill resulted.

Barbour Lake is another in which a large catch of fish possibly contributed to an unbalanced condition. On the first day of fishing in this lake 1,500 fishermen removed 60 pounds of fish per acre. During the first year 20,704 persons caught an average of 290 pounds of fish per acre. This heavy removal of adult fish and the development of excessive cover due to the infestation of the lake with a branched alga (*Pithophora* sp.) during the second year apparently caused an overpopulation of bluegill.

The unbalanced condition of Lamar Lake was caused by a heavy infestation of yellow bullhead. The bullheads either survived the poisoning of the lake area prior to stocking with hatchery fish or swam upstream over the spillway.

During the latter part of the second year of fishing in Marion Lake, a tremendous quantity of mud and silt was deposited throughout the lake and particularly in its upper portions as the result of the release of a large body of water that had been impounded by a road fill of a new highway. At that time the fish population was nearing an unbalanced state and several areas of the lake needed to be deepened. The lake was accordingly drained, the entire fish population eradicated, and certain areas of the lake dredged before it was restocked.

The five lakes that became unbalanced were marginally or sectionally poisoned with cubé powder containing 5 percent rotenone or with 5-percent emulsifiable rotenone as described by Swingle, Prather, and Lawrence (1953). They were then restocked with 150 to 200 largemouth bass fingerlings per acre. By this procedure it was possible to return the lakes to balance and thus to provide good fishing most of the time.

When Lamar Lake was unbalanced, baited wire baskets of the type described by Byrd (1952) were used to remove approximately 100 pounds of yellow bullheads per acre. This trapping no doubt helped considerably in correcting the crowded populations of bullhead and bluegill although marginal poisoning with rotenone was also used to thin these species.

Since all of the lakes were fertilized regularly, submergent, emergent, or marginal weeds did not constitute a serious problem in the management. Similar results were reported by Smith and Swingle (1942), Swingle and Smith (1947), and Swingle (1952).

It was necessary, however, to spray small areas of cattail (*Typha latifolia*) in all of the lakes each year. In one lake it was necessary also to

spray small areas of water lily (*Nymphaea* sp.) and watershield (*Brasenia Schreberi*). These plants were successfully controlled by periodically spraying with a mixture of 2, 4-D and diesel fuel (Swingle, 1952). A branched alga (*Pithophora* sp.) which grows very abundantly during the summer, especially when regular applications of fertilizer are made, became established in Butler and Barbour Lakes. A temporary control of this alga was obtained with the use of Delrad (Lawrence, 1954). More effective control was obtained, however, by treating Barbour Lake with 4 p.p.m. of liquid sodium arsenite during early spring (Lawrence, 1955).

Costs and Revenues of Lakes

The average cost of construction of the 11 state-owned lakes was approximately $460.00 per acre or $25,702.00 per lake. The cost of rotenone used in treating the lakes and drainage areas to kill native fish prior to impounding was approximately $54.00 per lake.

The average annual cost of fertilization was $27.50 per acre and the average annual cost of control of weeds, algae, and fish populations was approximately $1.50 per acre. After payment of the lake managers, the average net revenue derived annually from these lakes from the sale of fishing permits (50 cents per day for individuals over 16 years of age), boat rentals, and concessions was approximately $42.00 per acre or $13.00 per acre more than the annual cost of management.

Conclusions

The construction of public fishing lakes offers a practical method of providing good fishing in many areas of the Southeast that have insufficient fishing waters. Large annual yields of fish can be produced in lakes, provided the lake-sites are properly selected and the lakes are constructed so they can be fertilized and otherwise managed to maintain balanced fish populations.

Acknowledgment

The authors are indebted to J. M. Hester for his most valuable assistance in compiling the data for this manuscript. They also express thanks to others of the Alabama Department of Conservation who assisted with the preparation of the report.

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AGE AND GROWTH OF THE UTAH CHUB, *GILA ATRARIA* (GIRARD), IN PANGUITCH LAKE AND NAVAJO LAKE, UTAH, FROM SCALES AND OPERCULAR BONES

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Abstract

Age and growth were calculated for 222 Utah chubs collected from Panguitch Lake and 212 Utah chubs collected from Navajo Lake, southern Utah, in 1952–1953 from both scales and opercular bones. Scales were measured with the aid of a projector. Opercular bones were measured directly. The center of growth of the opercular bone is posterior to the posterior lip of the fulcrum. Correction for curvature is necessary in opercular bone measurements. Agreement of dominant age classes for successive years, agreement of empirical length-frequency modes of young fish with calculated length-frequency modes of lower age classes, agreement of ages as indicated by scales and opercular bones, agreement of age with sexually immature fish, and an increase in length with an increase in age are accepted as evidence in support of both methods. The opercular-bone method displays no appreciable advantages over the scale method.

Introduction

Among the non-game fishes that assume a role of importance in Utah is the Utah chub, *Gila atraria* (Girard), although it is not important economically. It has little value as a food fish, nor is it used in any commercial products. Recently, it has been used by fish hatchery people as a supplementary food material, but its utilization here is limited and has, as yet, reached no great proportions. It is of little value as a game fish since the sportsmen seldom attempt to catch them. Its real importance lies in the fact that the Utah chub reaches large numbers in areas in which more desirable game fish are present. Since the numbers of the chub are so large in some important trout waters, the competition for food and space with trout is suggested. Hazzard (1935) states that the Utah chub and trout are in direct competition for food in Fish Lake, Utah.

The Utah chub inhabits a wide range in the state. It has wide elevational and latitudinal distribution and is found in every drainage of the state. It is predominant at elevations between 5,000 and 9,000 feet. The lakes in which the Utah chub is present are also considered to be good habitat for trout and are being maintained and developed as such. Consequently when the Utah chub begins to outnumber the trout, cause for concern is justified. In the light of such developments a life-history study of the Utah chub is imperative.

One of the most important phases of a life-history study is that con-

cerned with age and growth. Collection of data was initiated in June of 1952 at Panguitch Lake and Navajo Lake in southern Utah.

McConnell (1952) used the opercular bone for establishing the age and growth of carp, *Cyprinus carpio* Linnaeus. The methods and techniques he used, particularly in the collection and preparation of the opercular bones for analysis, show improvement over the scale method. He also found less variation in the body length-opercular length relationship than in the body length-scale length relationship. LeCren (1947) presented similar evidence for the opercular bones of perch, *Perca fluviatilis* Linnaeus.

If the opercular bones of the Utah chub can be validly employed for the determination of age and growth, the method would be a valuable addition to a phase of the management of that fish. Consequently, the purpose of this paper becomes two-fold: (1) the establishment of the age and growth of the Utah chub, and (2) an evaluation of the opercular-bone method for the determination of age and growth of the Utah chub.

Methods Used

A total of 222 Utah chubs was collected from Panguitch Lake from June to September 1952, and in August and September 1953. Several methods of collection were employed in an effort to obtain an equitable distribution of length classes.

Shore areas were poisoned with a water suspension of rotenone to obtain the smallest fish. This method proved to be the most effective since the fish inhabited an area that abounded with emergent vegetation and in which a small seine was difficult to operate. A 30-foot minnow seine with a one-eighth-inch mesh, bar measure, was operated in waters not exceeding 3 feet in depth. This method was effective for collecting chubs from 70 to 130 millimeters in standard length. An experimental gill net (mesh size ¾ inch to 2 inches, bar measure) set in waters ranging from 10 to 30 feet in depth was sufficient to collect the remainder of the length classes.

The 212 chubs collected from Navajo Lake were taken between June and September 1952, and in September 1953, in a manner similar to that in Panguitch Lake. The smaller chubs not included in the experimental gill-net catch were taken with a 30-foot minnow seine. The seine was operated effectively since no emergent vegetation existed and the small chubs frequented shallow, sandy shore areas. The gill-net sets were made in various areas of the lake, but only those sets made in spring areas captured fish. The sets were made at depths ranging from 10 to 25 feet.

All fish except those less than 40 millimeters in standard length were processed for data immediately after capture. The smaller fish were preserved in a 10-percent formalin solution and examined later. Total, fork, and standard lengths, as described by Carlander (1950), were recorded to the nearest millimeter from a standard measuring board. Weights were taken to the nearest gram with a balance accurate to one-tenth of a gram. The sex and maturity were determined by examination of the gonads.

All the scales were taken from an area on the fish below and just anterior to the dorsal fin and above the lateral line on the left side. The scales were removed with a pen-knife using an anterior-posterior stroke. They were placed on a piece of 2-inch by 3-inch absorbent note paper which was folded and inserted into a coin envelope containing all pertinent data. The opercular bones were stored with the scales to avoid confusion.

The left opercular bone of each fish was taken by grasping the opercular assembly between the thumb and the fore-finger, lifting up and forward and tearing down and back thus eliminating the pre- and sub-opercular. This operation did no damage to the bone and was accomplished with a minimum of effort. In the few instances in which the left opercular bone was marred the right opercular bone was substituted. This procedure was considered safe with the evidence demonstrated by McConnell (1952) on the symmetry of carp opercular bones.

The scales were read and measured with the aid of a micro-projector. Magnification used was 31.3×. Best results were obtained by projecting the image on a dull surface. Surfaces painted with flat paint, faded yellow or beige in color, were excellent. Use of polarized light was attempted but no difference in the quality of projection was attained. Each scale was read several times (usually not more than three) without reference to preceding readings. When the readings agreed two or more times the ages were accepted. Measurements were made in the right anterio-lateral field of the projected image with the rule lying on an axis between the focus and the right shoulder of the scale.

Various attempts at projecting the image of the opercular bones proved unsuccessful. LeCren (1947) projected the images of perch opercular bones successfully with the aid of reflected and polarized light. This system was attempted, but the results were unsatisfactory in two respects: (1) the equipment used (an opaque projector) was impractical, both in size and operation, and (2) the size of the projected image was too large, resulting in confusion of annuli when measurement was attempted. Transmitted light with magnification produced an image without clear annuli. The addition of polarized light did nothing to improve the image.

The system finally adopted was that used by McConnell (1952) on carp opercular bones with modifications. The annuli could easily be seen by placing the opercular bone on a black background using reflected light. Since the opercular bones of the Utah chub were considerably smaller than those of the carp, calipers could not be used effectively in measurement. Instead, a white millimeter scale with black calibrations was used against a black background.

The opercular bone was placed with the center of growth directly over the zero of the scale. The most posterior margin was aligned over the calibrations, and measurements were taken on the straight line between the center of growth and the apex of the posterior margin. The dorsal margin overlapped onto the black blackground, and the black calibrations of the rule extended across the line of measurement. The scale was read directly through the bone with the aid of a hand magnifying glass (approximately

two to three power) to the nearest one-half millimeter. The mounted bones were treated the same as the dry bones.

Age Determination

The scales of the Utah chub are typically cycloid with pronounced shoulders on the lateral margins. Circuli are clearly observed with a magnification of 31.3× and closely follow the outline of the scale. All annuli, except the first, are pronounced and include prominent check marks in the anterio-lateral field.

The first annulus appears close to the focus. The circuli of the winter growth of the fishes' first year of life appear, upon superficial examination, very much like the circuli of the preceding summer growth. However, a definite check mark appears in both lateral fields for each first annulus. Empirical length-frequency histograms of zero-age fish captured late in the year places the mode close to, yet less than, the first-year mode of calculated length-frequencies for age group I (Fig. 1 and 2 A and C).

False annuli occur frequently in the anterior field beyond the third annulus. However, no check marks appeared in any of the other fields, and, consequently, they were eliminated. Examination of the scales of chub populations from Scofield Reservoir, Carbon County; Gooseberry Reservoir, San Pete County; Piute Reservoir, Piute County; Otter Creek Reservoir, Piute County; and Koosharum Reservoir, Sevier County reveal descriptions similar to those mentioned here.

The annuli of the opercular bones are represented by distinct, concentric bands and are essentially the same as those described by LeCren (1947) of perch opercular bones and by McConnell (1952) of carp opercular bones. Each band has two distinct elements: (1) a dark, narrow ring to the posterior, and (2) a transparent, wide band immediately anterior to the dark ring. It is assumed that the wide band represents the summer growth and the dark ring the winter growth. These bands are concentric in the outline of the opercular bone margin indicating that each dark ring represented the margin of the opercular bone at some time in the fish's life.

The first and second annuli are somewhat indistinct except on the line of measurement where they are placed with confidence. Many false annuli are present beyond the third year of growth. These false annuli, however, are easily identified. They are seldom as clear as the true annuli and appear only in the posterior field of the opercular bone. McConnell (1952) wrote of similar conditions in the carp opercular bones.

The annuli established on the opercular bones and those established on the scales of the same fish were remarkably similar in relation to adjacent annuli. The ages established by the two methods varied in some of the fish. The discrepancies in the Navajo Lake population amounted to 18 percent. Of these disagreements, 91 percent differed by two years. In the ages differing by one year, 50 percent of those based on the opercular bones had an age less than that represented by the scales.

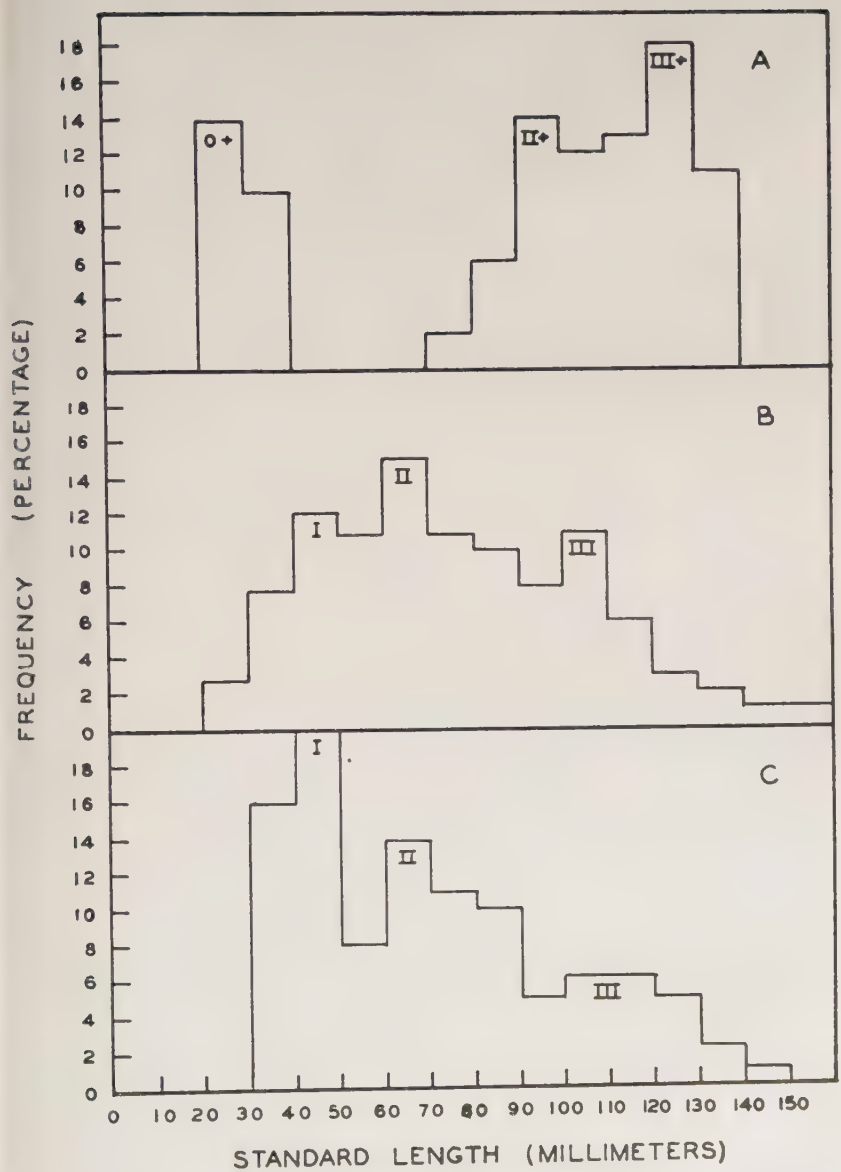

FIGURE 1.—(A) Empirical length-frequencies of 94 Utah chubs collected from Navajo Lake late in 1952 (B) Frequencies of calculated lengths from the opercular bones of the Utah chub collected from Navajo Lake in 1952 and 1953 (C) Frequencies of calculated lengths from scales of the Utah chub collected from Navajo Lake in 1952 and 1953. The modes represent year classes.

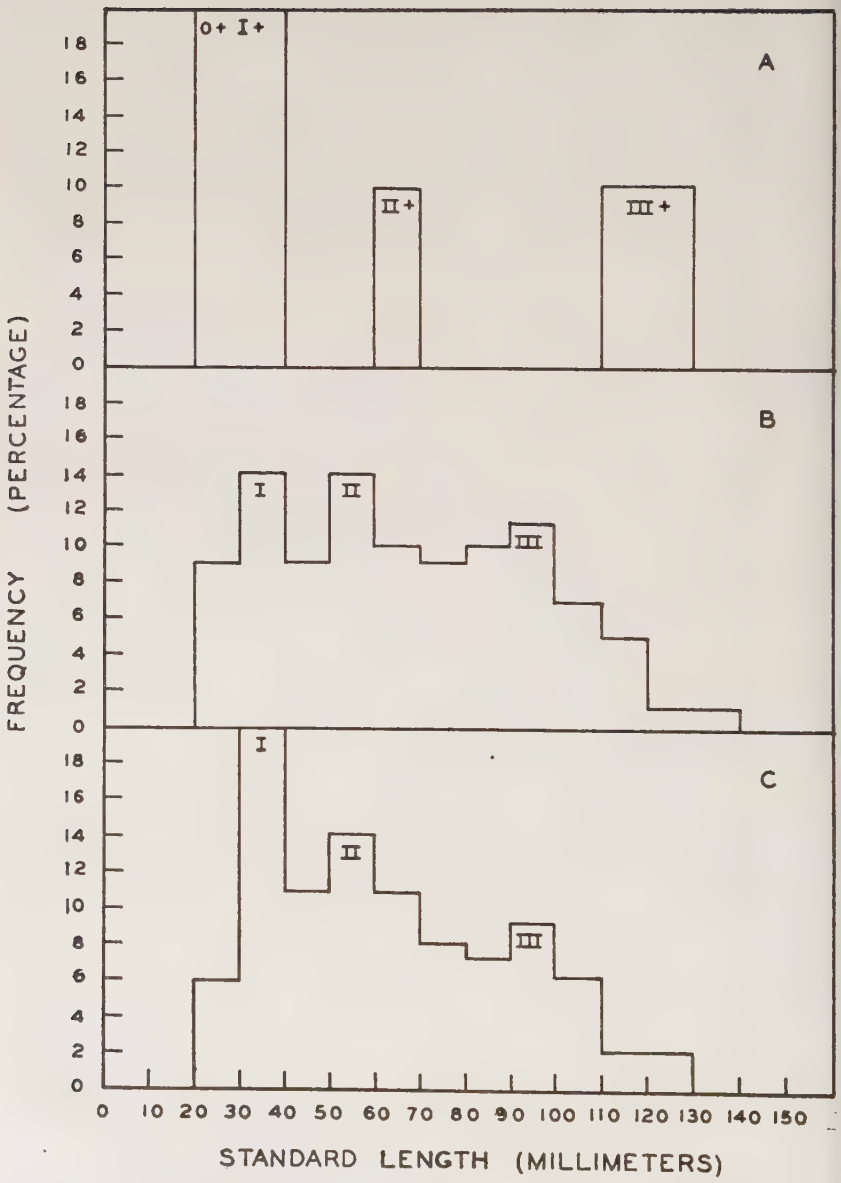

FIGURE 2.—(A) Empirical length-frequencies of 31 Utah chubs collected from Panguitch Lake late in 1952. (B) Frequencies of calculated lengths from the opercular bones of the Utah chub collected from Panguitch Lake in 1952 and 1953. (C) Frequencies of calculated lengths from scales of the Utah chub collected from Panguitch Lake in 1952 and 1953. The modes represent year classes.

The Panguitch Lake population differed in ageing by 13 percent, of which 83 percent varied by one year and 17 percent by two years. Fifty-six percent of the opercular bones differing by one year represented an age less than that based on the scales.

Since the data collected included no known-age fish, no attempt was made at the reconciliation of differences of ages. Those fish disagreeing in age were omitted from the calculation of past growth.

Calculation of Past Growth

The assumptions made for the calculation of past growth from scales also apply, with modifications, for the calculation of past growth from opercular bones. The prime assumption that the relation between the length of the fish and the length of the opercular bone can be expressed by a formula remains unchanged; that the opercular bone lays down an annulus similar to the scale is verified by LeCren (1947) for the perch and by McConnell (1952) for the carp; that the opercular bones of a fish do not vary in number is not questioned.

When measurement was initiated the center of growth of the opercular bone was assumed to be directly beneath the posterior lip of the fulcrum, the point of articulation with the cranium. LeCren (1947) and McConnell (1952) measured from the posterior lip of the fulcrum of the perch and carp respectively. This method is, however, invalid for the Utah chub. Growth of the fulcrum, instead of progressing perpendicular to the anterior-posterior axis of the opercular bone, actually pogresses along the axis, thereby removing the posterior lip of the fulcrum from the center of growth. Cross sections of 92 bones from both populations were examined until the center of growth could be determined from surface examination. The opercular bones were then measured from the true center of growth.

A further necessary adjustment is the correction for curvature. In effect, the original measurements are recorded on the leg of a right triangle with the line from the point of curvature to the edge of the opercular bone as its hypotenuse and the height to which the curve rises as its adjacent leg. (Fig. 3). The hypotenuse of this triangle is also the chord of an arc represented by the curvature of the opercular bone. These measurements represent an increment smaller than the true increment.

To adjust for this discrepancy, the opercular bone is placed convex side down on a flat surface. The height to which the opercular bone rises is measured and the point at which curvature begins is determined. The curvature is best described as parabolic and was fitted to the diagram by inspection. The annuli were recorded on the base of the right triangle and transposed to the curve by perpendicular projection. The new increments were then measured directly from the curve (Fig. 3). All diagrams were enlarged to 3× to facilitate measuring. The curvilinear measuring was accomplished with the use of a map measurer.

Corrections of measurement are considered necessary, since calculated lengths for uncorrected opercular-bone measurements displayed a real dif-

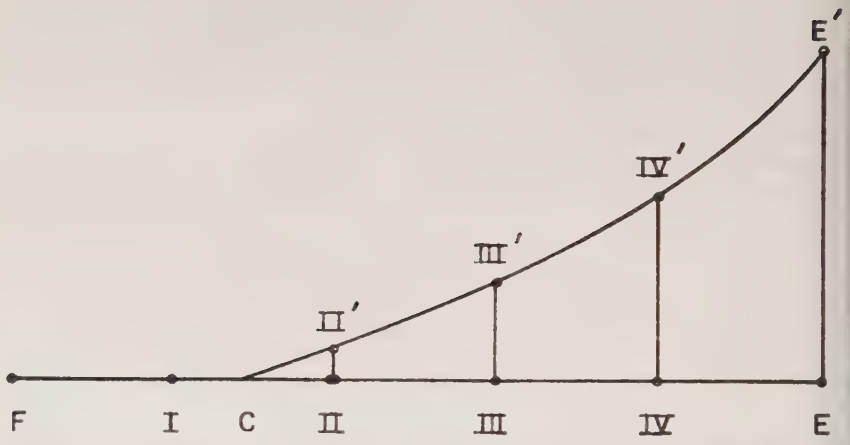

FIGURE 3.—Diagramatic representation of correcting measurements of the opercular bone. Line F-E represents the line on which measurements were recorded. Line F-C-E′ represents the opercular bone. Line E-E′ represents the height to which the opercular bone rose. Point C represents the origin of perceptible curvature. Increment II-III was the increment between the second and third annuli as recorded from the reading. Increment II′-III′ was the corrected increment from the diagram.

ference from lengths calculated from the corrected opercular-bone measurements and also from the lengths calculated from scale measurements.

The body-scale length (X 31.3) relationship of 222 Utah chubs from Panguitch Lake was best described by the formula,

$$L = 16.6 + 2.60\,R,$$

where L represents the standard length of the fish in millimeters at time of capture, and R represents the anterio-lateral radius of the scale (Fig. 4). Similarly, the body-scale length ($\times$ 31.3) relationship of 212 Utah chubs from Navajo Lake was best expressed by the formula,

$$L = 23.75 + 2.71\,R \text{ (Fig. 4)}.$$

The body-opercular length relationships were determined for the same fish that were employed for the body-scale length relationships.

The body-opercular length relationship of the Utah chub from Panguitch Lake was best described by the formula,

$$L = 4.263\,R^{1.070}$$

(Fig. 5). The formula that best described the body-opercular length relationship of the Utah chub from Navajo Lake is

$$L = 4.953\,R^{1.037} \text{ (Fig. 5)}.$$

Past growth was calculated from a nomograph essentially the same as the one described by Hile (1950). Calculations were made only for those fish that showed agreement in age by both methods.

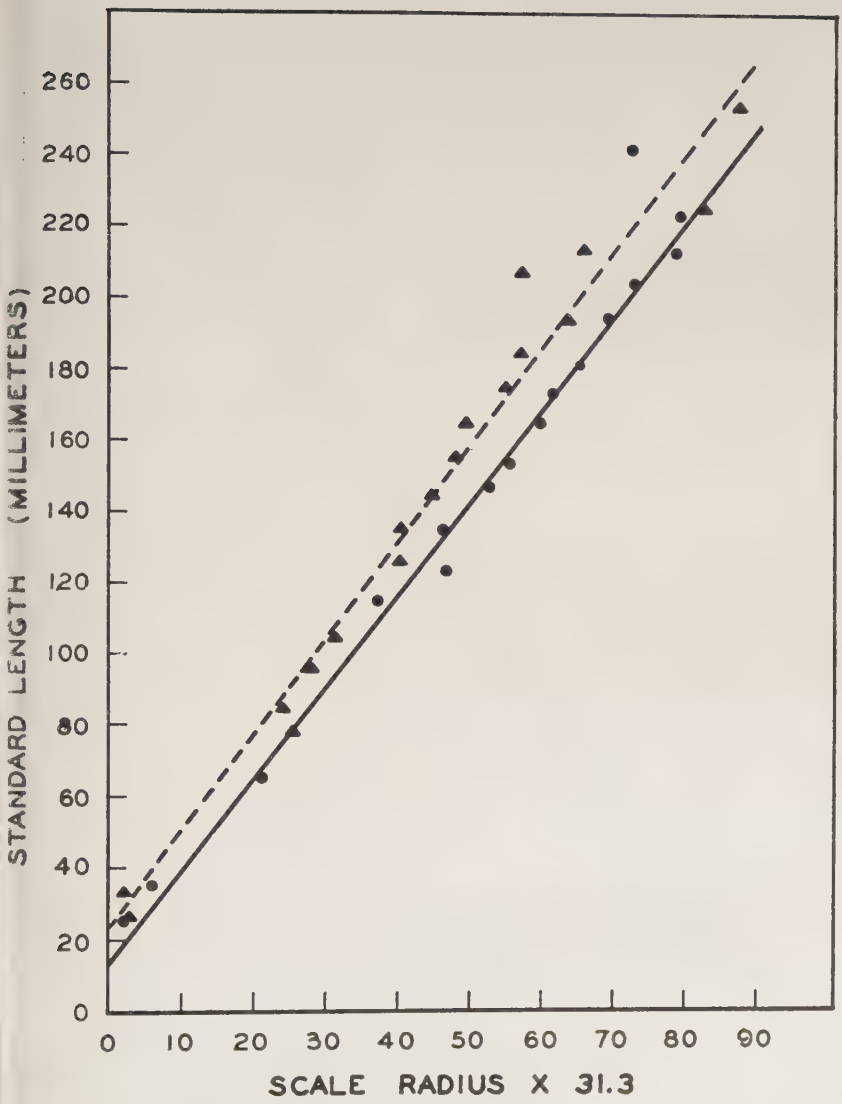

FIGURE 4.—Relationship of the standard length to anterio-lateral radius of the scale of the Utah chubs collected from Navaio Lake (dash) and Panguitch Lake (solid).

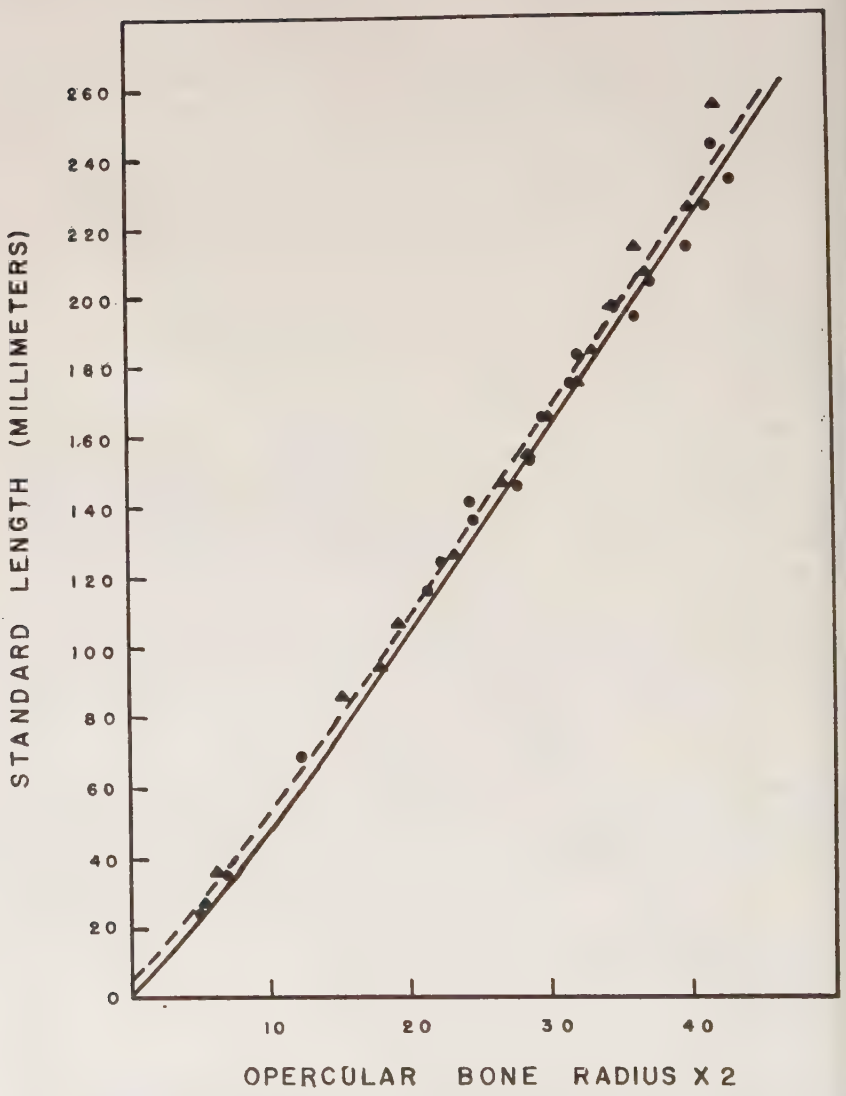

FIGURE 5.—Relationship of the standard length to the posterior radius of the opercular bone of the Utah chubs collected from Navajo Lake (dash) and Panguitch Lake (solid).

VALIDITY OF AGE DETERMINATION

Van Oosten (1929) listed several indirect methods for determining the validity of ages as determined from scales: (1) establish the time of annulus formation, (2) etablish the dominant age classes in collections of at

least two years, (3) determine number of annuli on scales from known-age fish, (4) compare empirical length-frequency modes of young fish with frequency modes of lengths calculated from the annuli, and (5) determine the sexual maturity of young, aged fish. Three of these methods are used in this presentation.

Collections of opercular bones and scales from fish of both populations were taken during 1952 and 1953. In 1951 only scales were taken from the fish of the Panguitch Lake population. An opportunity is thus presented for comparison of frequency peaks of year classes in successive years.

The number in an age class established by the scales of fish collected from Panguitch Lake in 1951 rose to a peak in age group III (Fig. 6). This peak progressed to age group IV in 1952 and to V in 1953. Similar-

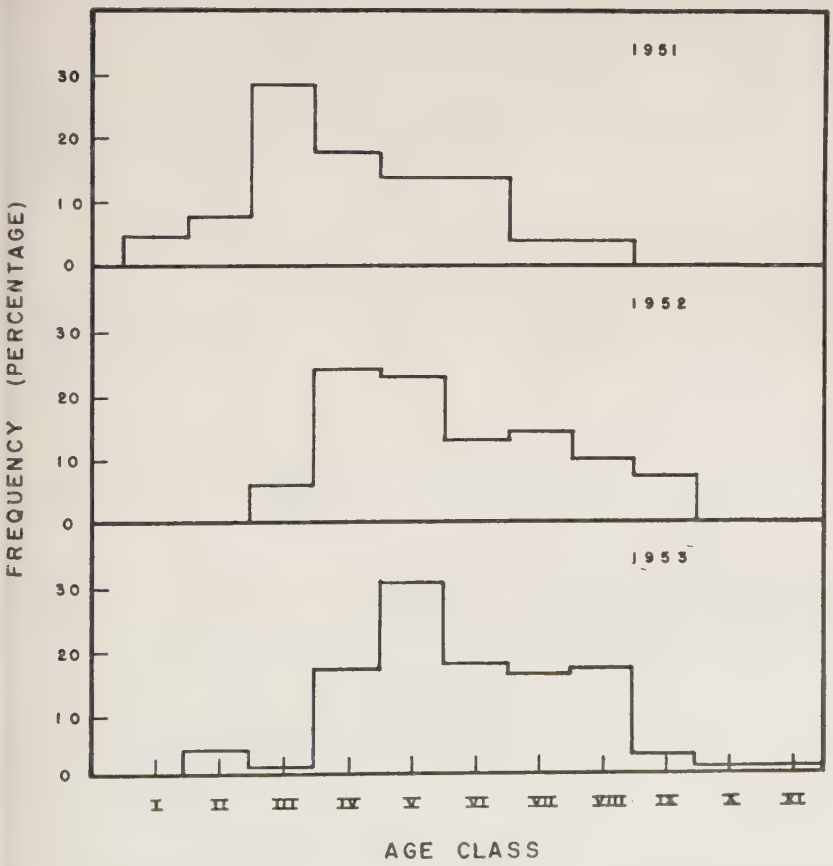

FIGURE 6.—Frequency distribution by age class of the Utah chub collected in 1951, 1952, and 1953 from Panguitch Lake. The ages were determined from scales. The dominant year class in 1951 is shown progressing in each successive year.

ly, the general pattern of the histogram advanced each age group each successive year. In the frequencies of the age groups established by the opercular bones, two peaks are apparent in 1952 (age groups IV and VII) (Fig. 7). Two peaks also appear in 1953 (age groups V and VIII).

For the age groups established from scales from the Navajo Lake population, the frequency peak fell in age group III in 1952 and progressed to age group IV in 1953 (Fig. 8). The dominant group of the age classes established by opercular bones consisted of III-year fish in 1952 and of IV-year individuals in 1953 (Fig. 9).

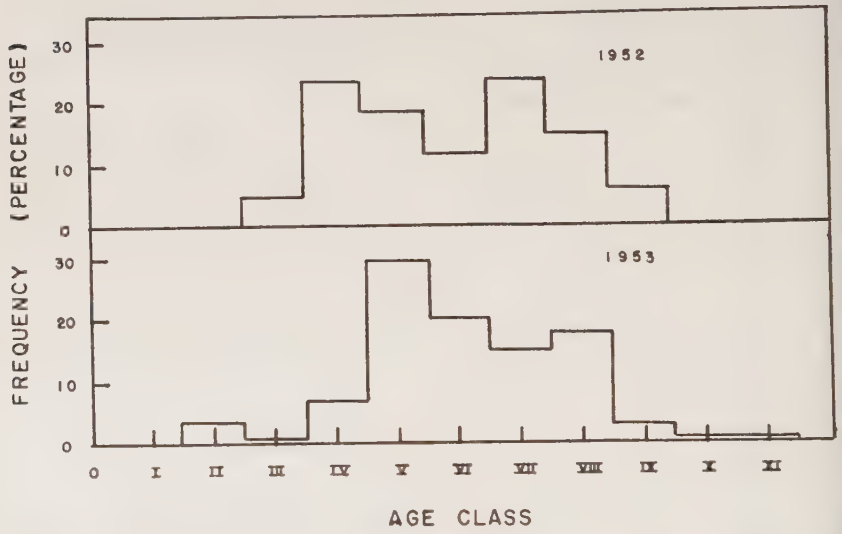

FIGURE 7.—Frequency distribution by age class of the Utah chub collected in 1952 and 1953 from Panguitch Lake. The ages were determined from opercular bones.

Close agreement of length-frequency modes of small, non-aged fish with calculated length-frequency modes is also apparent. The empirical length-frequency modes appear consistently in length classes slightly greater than those in which the modes of the calculated length-frequencies occur (Figs. 1 and 2). This relationship remains constant for both methods and both populations, indicating close agreement in these respects. Further, the empirical length frequency mode representing the O age class in the Navajo Lake population falls in the length group just slightly less than the calculated length mode for age class I. The Panguitch Lake empirical distribution did not show the O plus group as adequately as the Navajo Lake population. This was attributed to the small size of the sample.

Of the fish collected from Panguitch Lake that were sexually immature, 96 percent fell in age classes O and I. The remaining 4 percent were in age

class II. In Navajo Lake, 83 percent of the sexually immature fish were in age class O, 10 percent in II, and 7 percent in III. All of the sexually immature individuals in age classes II and III were males.

Accuracy of Growth Calculations

The calculated length-frequency modes for the two methods fall in the same length groups, indicating close agreement between the two methods (Figs. 1 and 2 B and C). Examination of the length-frequency histograms

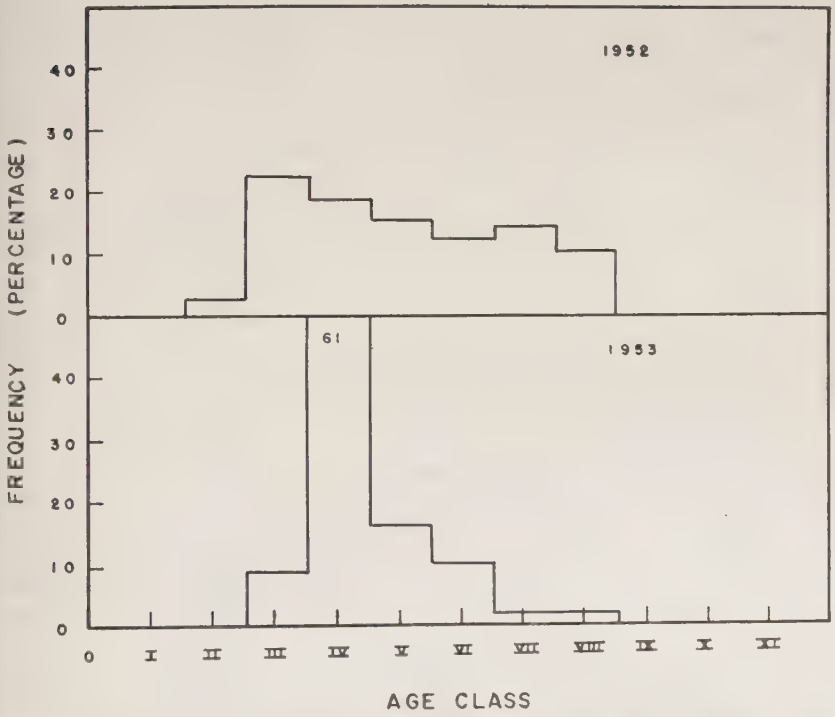

Figure 8.—Frequency distribution by age class of the Utah chub collected in 1952 and 1953 from Navajo Lake. The ages were determined from scales.

for the two populations, however, reveal differences in the variance of calculated lengths between the two methods. The modes representing age class I by the scale method are high and pronounced. The successive modes representing age classes II and III grow progressively smaller and less pronounced, indicating an increase in variance of the calculated lengths with age. The calculated length-frequency modes established by the opercular-bone method are comparatively level with little difference in height for

successive modes and remaining at a level consistent with the mode for age class II by the scale method. The calculated lengths of the individuals at the first annulus varied less from the mean when calculated from scales than when calculated from opercular bones. Conversely, at the third annulus, the calculated lengths by the scales varied more than the calculated lengths by the opercular bones.

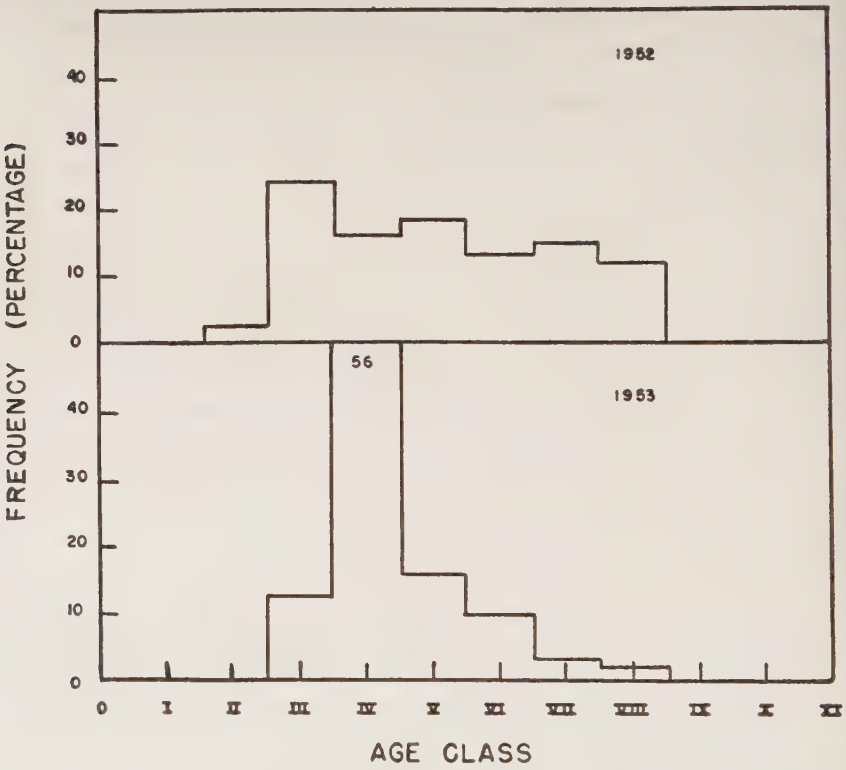

FIGURE 9.—Fequency distribution by age class of the Utah chub collected in 1952 and 1953 from Navajo Lake. The ages were determined from opercular bones.

The mean calculated lengths at the end of one year of life remained consistent through the age classes with allowances made for sample size (Tables 1 and 2). The absence in numbers of fish from age classes I, II, and III of the Panguitch Lake population is explainable by the increase of controlled poisoning of chubs in 1950. Age class I in the Navajo Lake population was so rare that it did not appear in the sample. This is attributed to controlled poisoning of chubs in 1951 and also a heavy freeze during the winter of 1951–1952 which may have increased the mortality of the smaller fish frequenting the shallow, shore areas.

TABLE 1.—*Mean standard lengths (millimeters) and annual length increments (millimeters) calculated from the scales of 174 Utah chubs collected from Panguitch Lake in 1952 and 1953 with a summary of mean standard lengths and annual length increments calculated from opercular bones*

Age class	Number	Mean length at capture	Mean calculated lengths at each annulus										
			1	2	3	4	5	6	7	8	9	10	11
I	7	52	34	...	...	...	...	...	...	...	...	...	...
II	5	126	40	90	...	...	...	...	...	...	...	...	...
III	2	127	36	59	93	...	...	...	...	...	...	...	...
IV	25	154	34	59	97	127	...	...	...	...	...	...	...
V	48	172	33	57	93	130	154	...	...	...	...	...	...
VI	30	182	35	58	93	125	148	165	...	...	...	...	...
VII	21	194	32	57	92	120	144	164	179	...	...	...	...
VIII	27	199	35	59	86	116	137	155	169	184	...	...	...
IX	6	207	35	57	84	119	135	154	171	187	198	...	...
X	2	233	39	56	82	114	138	159	178	196	212	223	...
XI	1	230	32	61	85	127	139	155	166	184	199	208	223
Weighted mean (scales)			34	59	92	124	146	161	173	185	201	218	223
Weighted mean (opercular bones)			38	61	94	125	148	163	175	186	201	219	225
Annual increment (scales)			34	25	34	32	22	19	15	15	12	10	5
Annual increment (opercular bones)			38	23	34	31	23	19	15	14	13	11	6
Number of fish			174	167	162	160	135	87	57	36	9	3	1

A close relationship also existed between the standard length and average calculated lengths for corresponding years of life.

Agreement of the average calculated lengths between the two methods is close (Tables 1 and 2). The discrepancies that are apparent are due almost entirely to the first year. After the first year the increments vary only slightly. The differences in the first year might be explained by the occasional difficulty encountered in measuring to the first annulus which was not at all times clearly defined in the opercular bone.

TABLE 2.—*Mean standard lengths (millimeters) and annual length increments (millimeters) calculated from the scales of 155 Utah chubs collected from Navajo Lake in 1952 and 1953 with a summary of mean standard lengths and annual length increments calculated from opercular bones*

Age class	Number	Mean length at capture	Mean calculated lengths at each annulus							
			1	2	3	4	5	6	7	8
II	36	101	39	69	...	...	...	...	...	...
III	21	130	41	70	110	...	...	...	...	...
IV	59	155	41	68	108	139	...	...	...	...
V	18	169	41	66	105	135	154	...	...	...
VI	11	184	41	67	108	137	156	171	...	...
VII	7	190	39	64	103	132	150	165	177	...
VIII	3	218	44	64	94	127	154	174	189	204
Weighted mean (scales)			40	67	107	137	154	169	181	204
Weighted mean (opercular bones)			41	69	109	138	155	170	181	201
Annual increment (scales)			40	27	39	30	20	15	13	15
Annual increment (opercular bones)			41	28	41	30	20	17	12	11
Number of fish			155	155	119	98	39	21	10	3

Evaluation of the Methods and Conclusions

The techniques used for the preparation of the scales for analysis differ for those employed for the opercular bones in that the bones need only be cleaned. The scales must be cleaned and mounted in suitable media on slides for projection. The opercular bones are simply read and measured directly, aided only by a hand lens.

On the other hand, the opercular bone requires additional measurements for curvature correction not necessary for the scales. The procedure for the correction of curvature is involved and increases chance for error, consequently detracting from the efficiency of the opercular-bone method.

The body length-scale radius and the body length-opercular-bone relationships are essentially similar. The body-opercular-bone relationship is slightly curvilinear. The curvilinearity affects only those fish below 20 millimeters in standard length. The remainder of the regression line is essentially linear. This is compared to the almost complete linearity of the body-scale relationship.

The calculated lengths for the first annulus varied less about the mode by the scale method than by the opercular-bone method. Variance of calculated lengths appeared to increase with age for the first three annuli by

the scale method. Lengths calculated from the opercular bone remained more constant about their respective modes for the first three annuli. In both methods, however, the individual calculated lengths varied about the same modes in their respective age classes.

The dominant age classes in the frequency distributions by age class for both methods were similar.

The mean, annual increments for the two methods differed only at the first annulus. Virtually, no differences occurred after the first annulus. The differences at the first annulus were attributed to some difficulty encountered in defining the first annulus in the opercular bone.

With the evidence presented, the opercular-bone method for age and growth determination of the Utah chub shows no appreciable advantages over the scale method.

Acknowledgments

Sincere appreciation is expressed to Dr. William F. Sigler, Head of the Wildlife Management Department, Dr. Lewis M. Turner, Dean of the School of Forestry, Dr. J. B. Low, Leader of the Utah Cooperative Wildlife Research Unit, Dr. Datus M. Hammond, Head of the Zoology Department, all of the Utah State Agricultural College, and Dr. Oliver B. Cope, Chief, Rocky Mountain Fishery Investigations, U. S. Fish and Wildlife Service, for their counseling and advisement. Thanks is also due William J. McConnell, Research Biologist, State of Utah Department of Fish and Game, for assistance in the collection of data.

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ELECTRIC SHOCKER DEVELOPMENTS ON SOUTHEASTERN TROUT WATERS

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Abstract

The many problems involved in making fish collections and population surveys in trout streams of the Shenandoah and Great Smoky Mountains National Parks led to an investigation of electro-fishing methods. These softwater streams have electrical resistivities ranging as high as 117,000 ohms cm^3. Grounded electrode systems of conventional design proved ineffective in such waters.

The Petty-type, alternate-polarity electrode system of original and modified design has been successfully tested in Park streams having resistivities of 32,000 to 117,000 ohms cm^3. The addition of trailers to the electrode system has produced substantial improvements in the strength and range of the effective, electrical field in the water. The alternating current power sources for the electrodes include a gasoline-driven portable generator and a battery-powered backpack unit which produce 240 and 250 volts respectively.

Introduction

The trout streams in the southern Appalachian Mountains, and more particularly in the Shenandoah and Great Smoky Mountains National Parks, are characterized by very soft waters which are generally clear, colorless, acid, and deficient in basic carbonates. They are generally steep and rough and the problems encountered in making collections of fish with seines or chemical agents have been difficult. The extremely high, electrical resistivities of these waters have precluded the application of electrofishing techniques which employ grounded systems with direct or alternating currents. Trials with paddle-type electrodes and 230 volts AC current failed and it was found that voltage gradients in the water dropped to zero when the electrodes were spaced 3 or more feet apart.

The recent development of the alternate-polarity electrode system by New York State biologists and its demonstrated superiority over grounded systems in moderately soft water prompted us to test it in National Park streams in Virginia, North Carolina and Tennessee. Extensive trials have been made in streams in which the resistivities were among the highest recorded for natural waters anywhere. The alternate-polarity system, with certain modifications to improve its effective range, has been successful in all waters tested. It offers promise of becoming a very useful tool for fishery workers in the southeast.

Alternate-polarity Electrode System

The principles and construction of the alternate-polarity electrode were described by Haskell (1954) and Petty (1955). Briefly, the system includes two or more electrodes, each about 30 inches long, attached linearly and connected electrically so that they are of alternate polarity (Fig. 1). Generous assistance was given by Messrs. Haskell and Petty in the construction of 3-, 5-, and 8-electrode systems which were tested in National Park streams. Several improvements were made in the construction of the shocker apparatus.

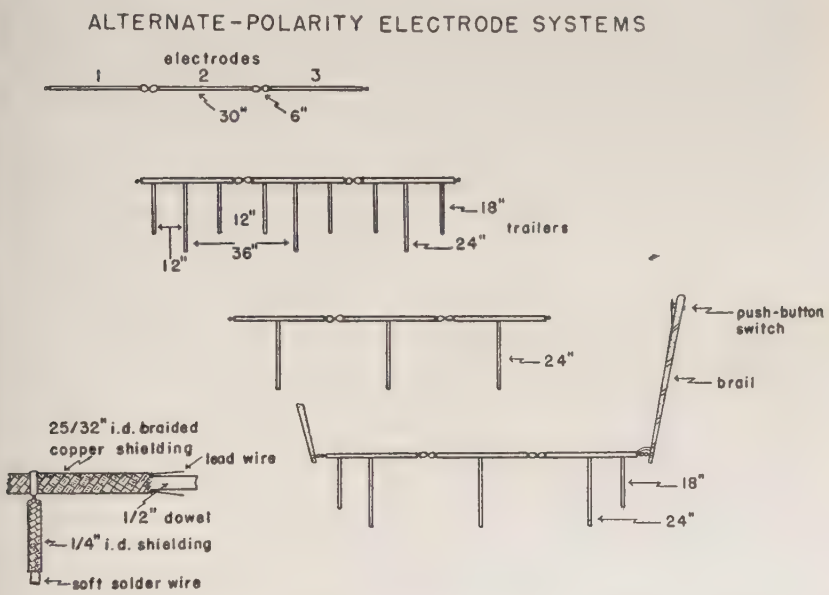

Figure 1.—Sketch of a 3-electrode, alternate-polarity system showing the arrangement of trailers tested in extremely softwater, trout streams of Shenandoah and Great Smoky Mountains National Parks in 1954 and 1955.

Neoprene-covered test prod wire (No. 18) was found to be superior to rubber-covered wire in resisting breakage and abrasion when used on brails and electrodes. Red and black prod wires were used on brails and electrodes to facilitate the alternate-polarity connections. A pushbutton switch of momentary contact type was inserted through the brail so that it could be quickly and easily manipulated by a small, wood lever. In addition, a neon, pocket-type testing light was recessed into the top of the brail and connected to the electrode side of the switch. When the switch is depressed and the circuit from generator to electrodes is functioning properly, the light glows. It also saves time and trouble in the searching for breaks or

interruptions in the circuit on the electrode side or on the generator side of the switch. The noise of falls or cascades often prevents one from hearing the generator motor, but the light in the brail indicates that the unit is operating.

Preliminary trials in the fall of 1954 were made in Park streams where resistivities ranged from 32,000 to 90,000 ohms cm^3. The electrodes were powered by a 230-volt, gasoline-driven generator producing 2,500 watts. Repeated runs over measured areas of water between check seines indicated that most of the trout and other fish could be removed in waters having 32,000 to 60,000 ohms resistivity. In streams where the resistivity exceeded 60,000 ohms cm^3, or in areas where the water was rough and very rapid, the effectiveness of the shocker was greatly decreased and the collection of fish was difficult. The electric field was apparently too narrow and weak and many fish were observed to escape around or over the electrodes. Since most streams in the Parks have resistivities ranging from 60,000 to 117,000 ohms cm^3, experiments were made to improve the efficiency of the electrodes in such waters.

Haskell (personal communication) suggested that the addition of trailers to the alternate-polarity electrodes might strengthen and extend the effective range of the electric force field. Several designs and arrangements were field tested (Fig. 1). Trailers of 18 and 24 inches long made of ¼-inch braided copper shielding were soldered into small ring-tongue, wire-end terminals which could be bolted to ½-inch clamps around the electrodes. Whereas it was desirable to have the trailers flexible to avoid wedging between rocks and debris, the shielding material used alone tended to curl. Lengths of solder wire threaded through the trailer and soldered into the terminals prevented the shielding from curling, but the wire would break and pierce the shielding after a day or two of use. Other trailers were constructed which had cores of the neoprene-covered, test prod wire. These trailers are flexible, strong, and less affected by abrasion on the streambed. Whenever trailers are mounted on adjacent electrodes in such a way that some overlap and short circuits might result, they are inserted into lengths of perforated, plastic tubing. The tubing permits the passage of electric current into the water but prevents short circuits due to direct contact of trailers of opposite polarity.

The trailer-equipped electrodes substantially improved the range and strength of the electric force field in the water. The immobilization of fish was more thorough and specimens were more easily captured in rapid, rough, and/or in the waters with highest resistivities. It was possible to stun and capture fish in deeper waters by elevating the main electrodes and permitting the trailers to hang towards the bottom.

Patterns of Force Fields in Water

The weight and drag of the electrode systems are important considerations to a small crew of operators. Thus it was necessary to determine the arrangements of trailers that would furnish the greatest improvement in

shocking fish with the least addition of weight. The electric fields produced in two streams were measured and plotted according to voltage gradients by means of a probe and a volt meter. Lines of equipotential were drawn and the area of paralysis voltage determined for each arrangement of trailers. According to Haskell (1954), a gradient of at least one volt per inch is required to stop a trout instantly. Therefore, any part of the electric field within the closed, one-volt line of equipotential was considered the area of paralysis voltage.

The greatest expansion of the electric field of force was observed when three trailers were attached to each electrode (Fig. 1). In the West Prong Little Pigeon River (48,000 ohms cm^3), the one-volt line of equipotential averaged 17.5 inches distant from the electrodes when no trailers were used, and 29.5 inches when three trailers were added to each electrode. The width of the effective field was therefore increased from 35 to 59 inches, an improvement of 69 percent (Figs. 2 and 3). In Porters Creek (86,000 ohms cm^3), the one-volt line averaged 14.5 inches distant from the electrodes with no trailers, and 21 inches when three trailers were attached to each electrode. The width of the effective field in this stream was increased from 29 to 42 inches by the addition of trailers, an improvement of 45 percent. In contrast, the addition of one trailer attached to the center of each electrode extended the field by an average of 51 per-

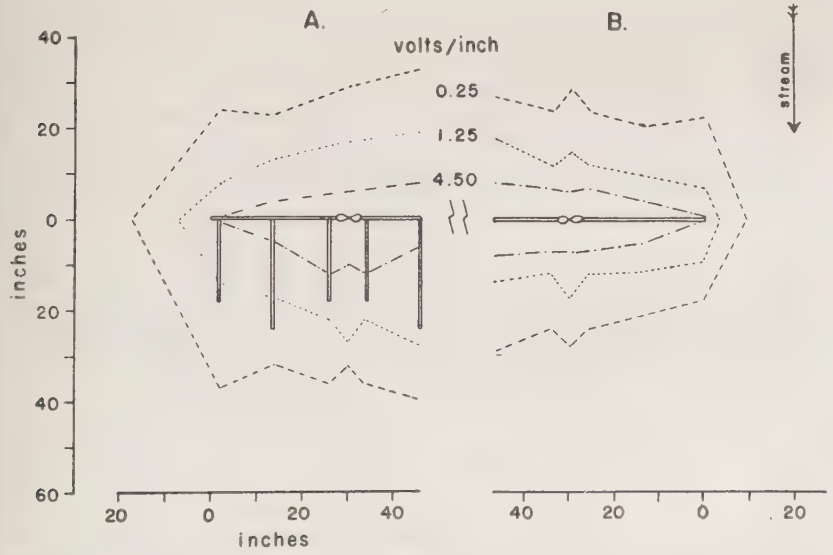

FIGURE 2.—Pattern of electric fields produced in Porters Creek (86,000 ohms cm^3) by alternate-polarity electrode systems. A., selected lines of equipotential surrounding system in which one 24-inch and two 18-inch trailers are attached to each electrode; B., similar lines of equipotential as they surround system equipped with no trailers.

cent in the West Prong Little Pigeon River and by an average of 28 percent in Porters Creek.

Since the trailers are easily attached or removed from the electrodes, and the various length electrode systems can be quickly substituted on the brails, the shocker apparatus is sufficiently flexible to meet a wide variety of stream conditions. One or two, 18-inch trailers are employed on each electrode in streams having resistivities between 32,000 and 45,000 ohms cm^3. Two to three trailers, 18 and 24 inches long are used when resistivities are between 45,000 and 65,000 ohms cm^3. In rough or high waters, and all waters over 65,000 ohms, two 18-inch and one 24-inch trailers are attached to each electrode.

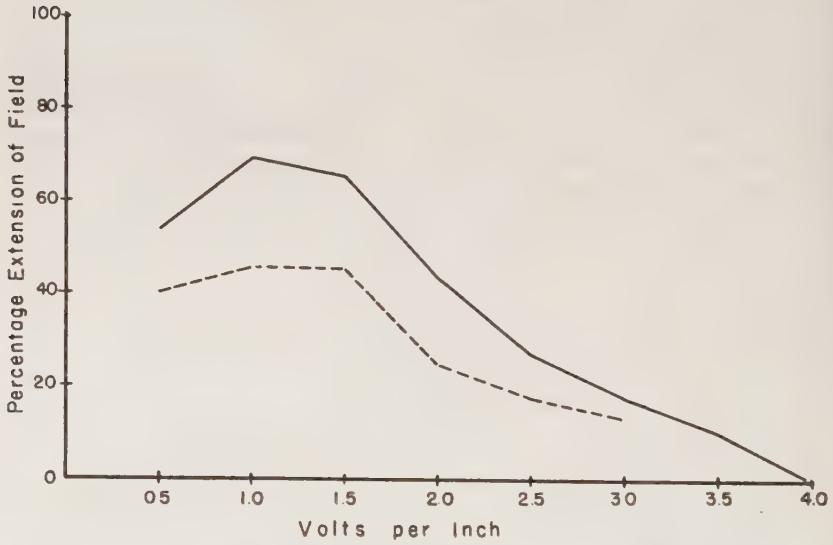

FIGURE 3.—Curves representing the percentage improvement in extending the electric field provided by alternate-polarity systems with three trailers attached to each electrode over systems with no trailers. Solid line: extension of field obtained in West Prong Little Pigeon River (48,000 ohms cm^3); dashed line, extension of field obtained in Porters Creek (86,000 ohms cm^3). A voltage gradient of one volt per inch is considered adequate to stun trout.

POWER SOURCES

High voltage is the primary requirement of a power unit for shocking fish in very soft waters. Rough terrain, limited access to many streams, and the small crew available forced us to consider the weight and portability of a power unit. In preliminary field trials of the alternate-polarity system, a 230-volt, 2,500-watt generator proved satisfactory, but it was

heavy, cumbersome, and difficult to handle along rough trails and streams. On a special order, a manufacturer modified a 115-volt, 600-watt AC generator to produce 240 volts. The unit is gasoline-driven and weighs only 72 pounds. It has given satisfactory service when used with the alternate-polarity electrodes under a wide variety of conditions in the field.

A backpack power unit of a type described by Haskell, MacDougal and Freeman (1954) has also been used successfully with the alternate-polarity electrodes in Park waters. It is mounted on a packboard, weighs 45 pounds, and is easily and comfortably carried. This unit produces 250 volts, AC, from its 6-volt motorcycle battery and can be used 2 to 3 hours before charging is necessary.

Use of Alternate-polarity Shocker

The trailer-equipped electrode system has been used in a large number of National Park and state streams. Good results with game and rough fishes have been consistently obtained in large and small streams, in turbulent and flat waters, and at water temperatures ranging from 39° to 72° F. It has been effective on all species of fish encountered, including brook trout, rainbow trout, brown trout, white sucker, hogsuckers, cyprinids, smallmouth bass, largemouth bass, other centrarchids, percids, cottids, bullheads and American eel. Little or no mortaliy has occurred on stunned and captured fishes.

Whereas it is desirable to make as many as four trips through a blocked off area to collect most of the fish, usually about 65 percent of the collectible specimens are taken on the first trip. Often no fish are captured on the third and fourth trips, but in turbulent or high waters up to 20 percent of the total number collected may be taken on the fourth trip. The investigator should satisfy himself that every possible fish is collected regardless of the number of trips required. Obviously the results per trip will vary according to the size and skill of the crew, the conductivity of the water, and the character of the streambed. No comparisons of collection data are presented here because of the variety of streams worked, usually with the assistance of different and untrained crews.

The design of the alternate-polarity shocker and the high voltage employed requires that certain precautions be taken for the safety of personnel and equipment. The electrode operators wear rubber gloves and all crew members wear rubber footgear. The generator is equipped with a circuit breaker to protect it from overloads. The pushbutton switch on the brail provides one of the quickest methods of breaking the circuit if a crew member falls into the water.

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ANGLER'S HARVEST, GROWTH RATE AND POPULATION ESTIMATE OF THE LARGEMOUTH BASS OF BROWNS LAKE, WISCONSIN

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Abstract

An apparent abundance of largemouth bass (*Micropterus salmoides*) below legal length in Browns Lake, Wisconsin, led to an experimental liberalization of angling regulations in which the minimum size limit was eliminated and the open season was lengthened. As a start towards the evaluation of these measures a study has been made of the angler's harvest and of the growth rate of the bass, and the size of the bass population has been estimated.

A partial creel census indicated that an angling pressure amounting to 75 hours per acre harvested a total of 2,671 largemouth bass in 30,091 hours. Sixty-two percent of the largemouth bass were over 10 inches long and 38 percent less than 10 inches, the former minimum legal size. The earlier opening of the season permitted capture of more large individuals.

The relationship between the anterior scale radius (inches $\times$ 44) and the total length (inches) of largemouth bass was described satisfactorily by the equation $S = 0.1813\,L^{1.3613}$. Calculations of growth in length based on this relationship were made by a nomograph for 889 angler-caught and 881 seine-caught fish. Largemouth bass reached a size of 10 inches in 3 to 4 years. Age-groups IV and V dominated the catches.

The total population of largemouth bass was estimated by the mark and recapture technique to include 21,980 fish over 6 inches long. The validity of this estimate was confirmed independently by DeLury's method involving a time series of catch-effort statistics. The estimated population amounted to 55.5 individuals or 33.3 pounds per acre, a figure similar to most reported for other stocks. Angling mortality was estimated at 12 percent and total mortality at 24 percent.

Introduction

The recent trend in the management of largemouth bass populations has been toward liberalized regulations. In the TVA lakes, Ohio, and other places there are no restrictions on angling for this species. Wisconsin presently maintains a daily bag limit of 5, a closed season, and until 1954 a minimum size limit of 10 inches.

Lake surveys in 1951 indicated an abundance of undersized largemouth bass which appeared to have a slower-than-average rate of growth. Consequently Browns Lake was chosen in 1952 for an experimental study of effects of the removal of size limits on largemouth bass and of a 5 week earlier opening date. The study was expanded in 1953 by means of a Dingell-Johnson federal aid project.

To evaluate the results of the more liberal regulations it was necessary

to determine: (1) the standing population of largemouth bass, (2) the rate of exploitation, (3) the age composition, and (4) the rate of growth. This paper deals with the initial work completed during 1953.

Limnological Conditions in Browns Lake

Browns Lake is located in Racine County near Burlington. It covers 396 acres, has a maximum depth of 44 feet, and an average depth of 12 feet. Contours are gradual and regular with the exception of one small area (Fig. 1). The lake is surrounded by wooded hills except for the south shore which is flat. The shoreline is irregular, and the lake is composed of a series of shallow bays. The bottom is sand, gravel, and marl. Easy access for anglers is provided by a public boat landing. Several boat liveries, homes, and summer cottages occupy nearly the entire shoreline.

Summer stratification is limited to one depression, and dissolved oxygen is present at all levels in sufficient quantities to support fish life. Water temperatures ranged from 82° F. at the surface to 76° F. at 15 feet on August 20, 1953. Maximum Secchi-disc readings on the same date were recorded at 8 feet. The water is hard-methyl-orange alkalinity about 130 p.p.m.

Rooted vegetation is very abundant in Browns Lake, wild celery (*Valisneria americana*), sago pondweed (*Potomogeton pectinatus*), and muskgrass (*Chara* sp.) are the common species found.

The fish population of Browns Lake is dominated by largemouth bass and panfish. Bluegills (*Lepomis macrochirus*) and black crappies (*Pomoxis nigromaculatus*) are important in the catch. Most of the fishes common to the lakes of southern Wisconsin are represented in the fauna of Browns Lake. Adequate spawning areas are apparently available, since young-of-the-year fish were readily taken in shoreline hauls with a small-mesh minnow seine. Reproduction of all species appeared to be good in 1953.

Creel Census

A creel census of the largemouth bass fishery was conducted from May 16, the opening date, to October 9. The fishing pressure had declined greatly by October 9 and further censusing was impractical.

Because the number of cottages, resorts, and points of access made complete coverage impossible, a sampling system was established. A census clerk operated at the lake every day from 6:00 A.M. to 10:00 A.M. and from 3:00 P.M. to 9:00 P.M., and on 2 days each week from 10:00 A.M. to 3:00 P.M.; thus the total census period was 80 hours per week. The census covered approximately 80 percent of the normal fishing week. The two long days (6:00 A.M. to 9:00 P.M.) were different each week, so that individual days were checked twice during each 7-week period.

Since census-takers made the majority of their contacts on the lake while the angler was fishing, only a few completed trips were tallied. In

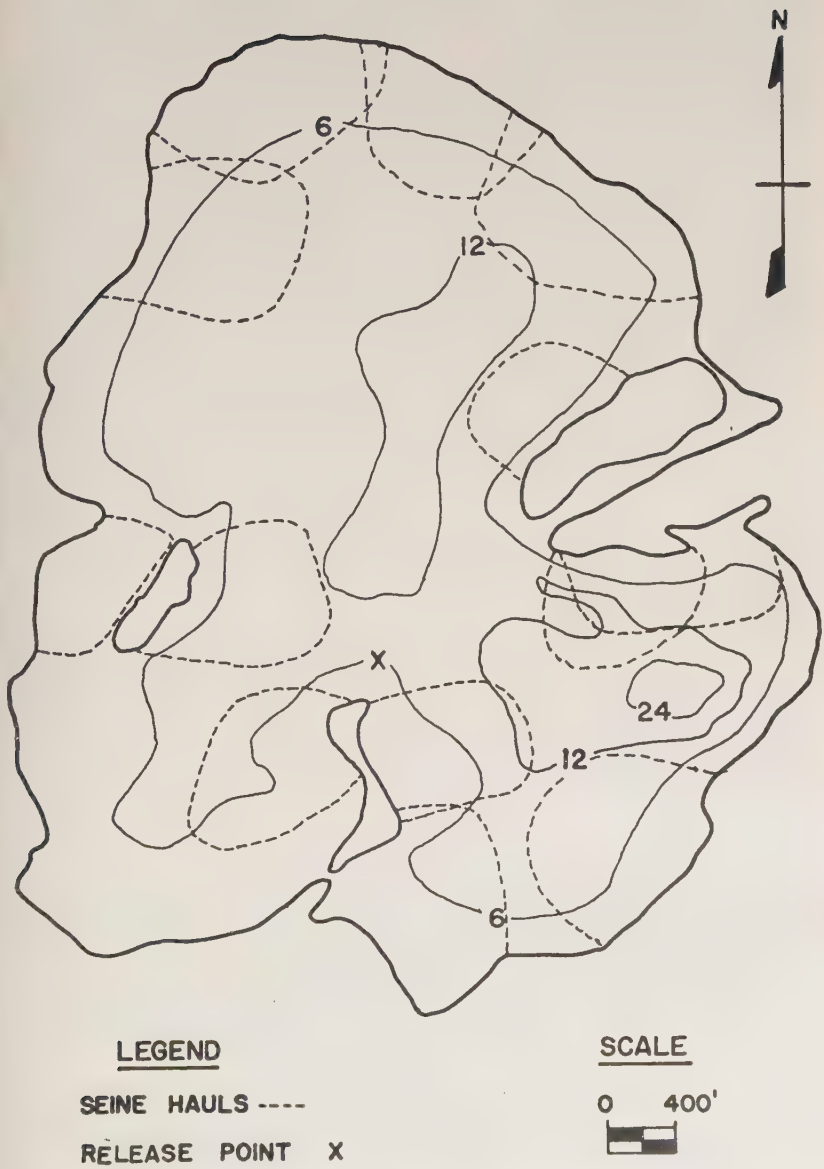

FIGURE 1.—Outline map of 396-acre Browns Lake, showing location of seine hauls.

the event of a sudden storm, the operator went to a boat livery to contact the maximum number of fishermen leaving the lake.

The clerk also made boat counts, the first at the start of his tour and later ones at two hour intervals. The catch for each day was estimated on the basis of the anglers checked, fish tallied, and the boat counts.

Sources of error.—Census methods tended to over-estimate the catch of largemouth bass for several reasons. First, the fishing from all boats was considered to be for bass, whereas some fishermen actually were concentrating on panfish and caught few or no bass. Secondly, the census clerks concentrated their efforts on boats that were engaged in bass fishing; and the average number of bass caught per boat therefore tended to be too great. Finally, a number of the better local fishermen who quickly became acquainted with the census and its objectives were more willing to cooperate than others.

Most of the early morning fishermen were checked on the clerks first round of the lake, but darkness prevented any attempt to determine the amount of fishing after 9:00 P.M. This loss of contacts was small as few boats were still on the lake at dusk. The period from 10:00 A.M. to 3:00 P.M. was censused only two days a week, but as this time was poor for bass fishing, only a few fish were missed. No census was made from October 9 to the close of the season (January 15) of the following year. By October very little fishing was done, and ice fishing for largemouth bass during the winter is poor. The late fall and winter catch was considered to be negligible.

Angler's catch.—The census led to the estimate that 15,332 fishermen spent 30,091 hours on the lake during the period from May 16 through October 9, 1953, and caught 2,671 largemouth bass (Table 1). Sixty-two percent of the fish were 10 inches or longer (Fig. 2). The number of boats actually contacted was 37 percent of the total number counted. Browns Lake was subjected to 75 hours per acre fishing pressure which provided a yield of 6.7 bass of all sizes per acre, or about 4 pounds per acre by weight.

The fishing effort on Browns Lake is similar to that on other heavily fished waters. About 100 hours per acre were exerted for the entire year on Escanaba Lake, in northern Wisconsin (complete creel census; unpublished data). Bennett (1952) reported fishing pressure at an average of 100 hours per acre on a few small ponds in Illinois, Moyle and Franklin (1954) reported fishing pressure from 3.5 to 122 hours per acre for 12 Minnesota Lakes in 1952–53. Their figures include winter angling and spearing.

Many large fish were taken during the first few days of the census operations. Bennett, Thompson, and Parr (1940) have advanced the theory that largemouth bass become "bait-shy" quickly during a period of heavy fishing. Apparently this thesis holds for the bass in Browns Lake. Census clerks tallied 9 fish with total lengths over 18.5 inches during the first 3 weeks of the season. Not until 6 weeks later was another large bass caught, and only 5 were taken during the last 12 weeks of the season.

Topel (1949) observed that large bass spawn earlier than small ones. Also, fish-culturists say that reproduction from very large fish is not as successful as from those 14 to 16 inches long. Evidently the early opening of the season at Browns Lake provided an opportunity to take some of these large fish but not enough to limit natural reproduction. The view that nesting bass can be easily caught was not substantiated by creel-census data and the population estimate to be described later.

TABLE 1.—*Estimated number of fishermen, total hours fished and number of largemouth bass caught during a 21-week creel census conducted on Browns Lake in 1953*

Fishing period	Number of anglers	Total hours fished	Number of largemouth bass caught		
			Shorter than 10 inches	10 inches or longer	All lengths
May 16-22	389	1,144	16	60	76
May 23-29	531	1,136	57	148	205
May 30-June 5	1,106	2,100	111	179	290
June 6-12	864	1,900	58	123	181
June 13-19	669	1,820	47	159	206
June 20-26	940	1,652	96	101	197
June 27—July 3	597	1,564	182	76	258
July 4-10	932	1,646	56	49	105
July 11-17	841	2,332	43	41	84
July 18-24	668	1,588	30	59	89
July 25-31	743	1,828	39	52	91
August 1-7	598	1,228	43	41	84
August 8-14	1,510	2,184	69	105	174
August 15-21	959	1,596	24	68	92
August 22-28	1,252	1,884	87	117	204
August 29—Sept. 4	743	1,268	49	90	139
Sept. 5-11	774	1,392	34	60	94
Sept. 12-18	318	436	13	19	32
Sept. 19-25	359	524	12	10	22
Sept. 26—Oct. 2	361	592	11	27	38
Oct. 3-9	178	277	0	10	10
Total	15,332	30,091	1,077	1,594	2,671

AGE AND GROWTH

Since the effect of liberalized fishing on the largemouth bass population may be judged by the changes in age composition of the population and in the rate of growth, a study was made of conditions at the start of the experiment. Scale samples were taken from all angler-caught fish checked by creel census clerks, and others were collected during the population estimate conducted in late September. Scale samples from all fish were removed from the area midway between the lateral line and the dorsal fin and directly below the insertion of the dorsal fin. Plastic impressions of the scales were read at a magnification $\times$ 44. Measurements were made from the focus along the anterior scale radius.

Age composition.—The age composition of the angler-caught fish and the fish from seine hauls is strikingly similar (Table 2). The seine hauls, as anticipated, caught more I-group fish than did anglers but the distri-

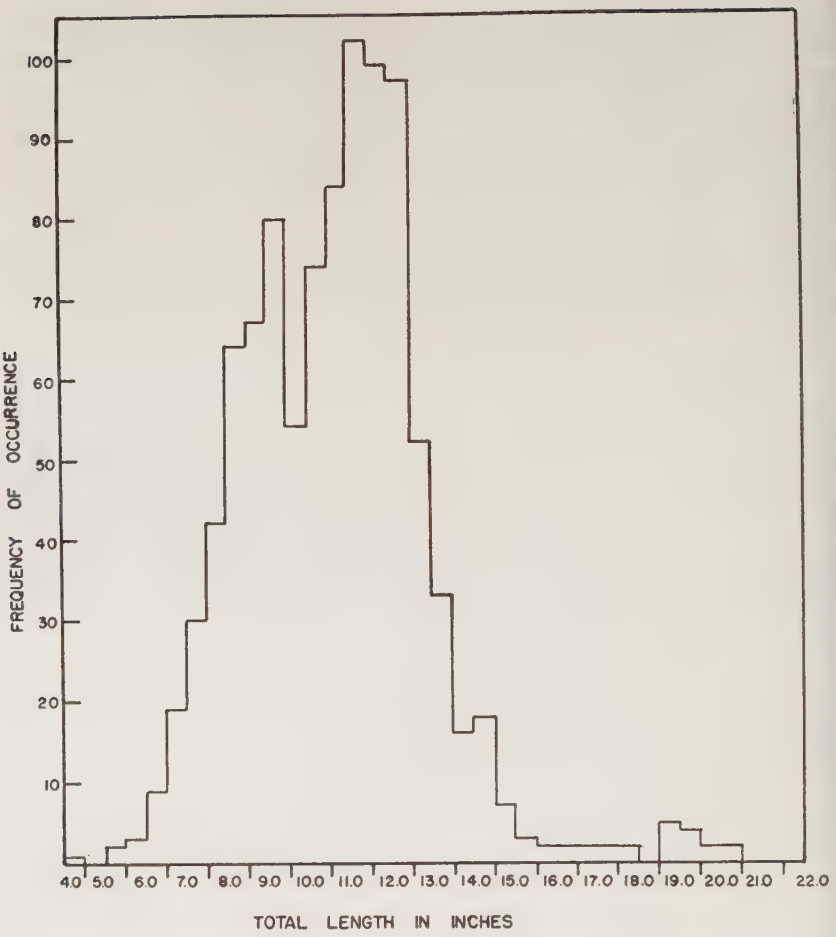

FIGURE 2.—Length frequency distribution of 980 angler-caught largemouth bass obtained by a creel census on Browns Lake.

bution of the other age groups matches very closely. Fish of age-group II made up 27.7 per cent of the total catch by anglers and 24.4 percent of the seine sample; age-group IV composed 31.8 percent of the anglers' catch and 31.0 percent from the seine; and age-group VI contributed 5.1 percent of the anglers' catch and 4.0 percent of the catch by the seine. The anglers were not harvesting age group III in as large numbers as anticipated. When ages were determined for the fish from the seine hauls, it became apparent that this group was not present in as large numbers as age-groups II or IV. The anglers were actually catching this group in slightly greater proportion than the seine hauls.

Obviously anglers were keeping catchable fish in much the same proportion as the seine. The I group (3.5 to 6.5 inches) did not enter the creel in appreciable numbers, as expected, and the large fish were caught in lower proportion than in the seine hauls. Age-groups VII and VIII were twice as abundant in seine hauls as they were in the creel.

Body-scale-relationship.—Different methods have been employed for the comparison of growth from measurements of black bass scales. Stroud (1948) assumed a constant body-scale ratio in his work with the basses and black crappie in the Norris Reservoir. Bennett, Thompson and Parr (1940) reported a straight-line relationship, with an intercept at zero, between scale radius and body length in their work at Fork Lake, Illinois. However, their fish ranged from 5 to 11 inches in length only.

TABLE 2.—*The number and percentage of the total of various age groups making up the angler-harvested and seine-caught samples of largemouth bass from Browns Lake*

Age group	Anglers		Seine	
	Number of fish	Percentage of total	Number of fish	Percentage of total
I	40	4.5	125	14.2
II	246	27.7	215	24.4
III	159	17.9	101	11.5
IV	283	31.8	273	31.0
V	98	11.0	102	11.6
VI	45	5.1	35	4.0
VII	7	0.8	14	1.6
VIII	4	0.4	10	1.1
IX	6	0.7	2	0.2
X	...	.....	2	0.2
XI	...	.....	1	0.1
XII	1	0.1	...	.....
XIII	...	.....	1	0.1
Total	889	100.0	881	100.0

In the study of the body - scale - relationship of largemouth bass of Browns Lake, "key scales" were selected from the third scale row above the lateral line and directly below the insertion of the dorsal fin. Specimens were selected to insure an adequate number of key scales from fish in each ½-inch group. Young-of-the-year as small as 1.3 inches which already had scales were collected along the shoreline with a small-mesh minnow seine.

The body-scale-relationship of largemouth bass was determined by the methods of least squares fit to logs. The line of best fit to these data is described by the formula:

$$S = 0.1813\ L^{1.3613}$$

where S equals the length of the anterior scale radius (inches X 44) and L the total fish length in inches (Fig. 3).

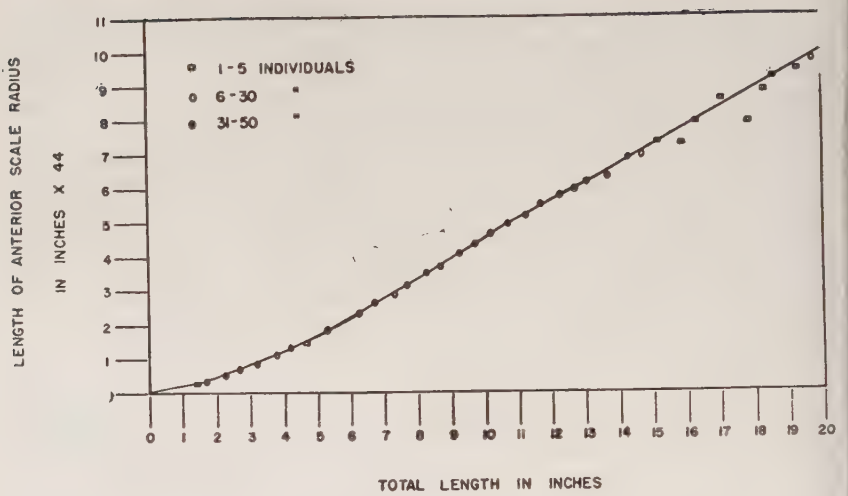

FIGURE 3.—Body-scale relationship of largemouth bass from Browns Lake. The dots give the empirical data; the curve is a graph of the equation given in the text.

A nomograph similar to the one described by Hile (1950), and based on the preceding equation was employed for all calculations of growth.

To compare the results from back calculations using different methods, a fish was selected at random and growth calculations made. A straight-line relationship with zero intercept, which assumes the body-scale relationship is constant for all lengths of the fish, differed considerably from calculations obtained by the derived formula (Table 3). This clearly demonstrated that this frequent assumption was in error for this population; and that, had it been used instead of the formula, an error of considerable magnitude would have been introduced into the calculations. Table 3 shows that a straight-line relationship with a one inch intercept, in which the ratio is a function of fish length follows a conicsection hyper-

TABLE 3.—*Comparison of the calculations of total length (inches) of a Browns Lake largemouth bass, made by different methods*

Method	Calculated total lengths at end of year of life				
	1	2	3	4	4+[1]
Derived formula[2]	3.8	6.0	8.2	10.7	12.7
Straight line (intercept, 0)	2.4	4.7	7.0	10.1	12.7
Straight line (intercept, 1 inch)	4.0	5.9	7.8	10.5	12.7
Straight line (intercept, 2 inches)	5.6	7.2	8.8	10.4	12.7

[1]Size at capture.
[2]See text.

bola, was quite close to the calculations made by the derived formula. A 2 inch intercept, straight-line relationship was unsatisfactory.

Growth rate.—To successfully assess the rate of growth of Browns Lake largemouth bass, it was necessary to compare the methods of obtaining samples, seining and angling. Age determinations were made on fish from four seine hauls and compared with angler-caught fish. Comparison of the two groups of largemouth bass showed very little difference in growth below age group VI. Beyond this group the numbers involved were too small to enable valid comparison. Apparently the seine and the anglers selected largemouth bass from the population in a similar manner, and both failed to sample fully age group O, and the anglers alone failed to sample age group I.

Since it had been determined that both methods were selective in the same manner, all of the bass were combined into one sample to determine the growth rate (Table 4). The Browns Lake largemouth bass exhibited

TABLE 4.—*Calculated total lengths (inches) of largemouth bass taken by anglers and by seine in Browns Lake*

Age group	Number of fish	Calculated total length at end of year of life												
		1	2	3	4	5	6	7	8	9	10	11	12	13
I	165	3.6	....	....	....	....	....	....	....	....	....	....	....	....
II	461	3.2	6.8	....	....	....	....	....	....	....	....	....	....	....
III	260	3.4	6.5	9.2	....	....	....	....	....	....	....	....	....	....
IV	556	3.9	6.7	8.8	10.8	....	....	....	....	....	....	....	....	....
V	200	3.6	6.6	8.7	10.3	11.8	....	....	....	....	....	....	....	....
VI	80	3.2	6.6	8.9	10.4	11.6	12.9	....	....	....	....	....	....	....
VII	21	3.9	7.2	9.8	11.4	12.8	14.0	15.5	....	....	....	....	....	....
VIII	14	3.9	7.7	10.5	12.5	14.3	15.7	17.0	18.0	....	....	....	....	....
IX	8	3.7	7.4	10.3	12.4	13.9	15.3	16.6	17.7	18.6	....	....	....	....
X	2	4.3	6.7	9.5	11.7	13.2	14.4	16.1	17.3	18.0	18.7	....	....	....
XI	1	4.9	7.6	9.5	10.5	12.2	13.5	15.2	16.7	18.1	19.0	19.7	....	....
XII	1	2.9	6.3	9.3	12.4	14.3	15.7	17.0	18.3	19.4	20.5	21.0	21.6	....
XIII	1	5.0	8.4	10.2	11.6	12.5	14.1	15.4	16.4	16.4	17.2	18.0	19.4	20.1
Average		3.6	6.7	9.0	10.7	12.0	13.6	16.2	17.8	18.4	18.8	19.6	20.5	20.1
Annual increment		3.6	3.1	2.3	1.7	1.3	1.6	2.6	1.6	0.6	0.4	0.8	0.9	−0.4

a steady decline in the annual increment of growth for the first 5 years followed by an annual increment increase for the next 3 years. The rate then decreased sharply for the much older individuals. Normally, it is found that growth is slower in each succeeding year of life. Bass took 3 to 4 years to obtain the former legal limit of 10 inches.

The average calculated lengths for the various age groups agreed well with the length-frequency distribution of all fish captured in the seine hauls during the population estimate operations which were conducted in September, a time when annual growth is about complete (Fig. 4). The calculated lengths for age groups II through VI fall very close to the peaks of the distribution of seine caught fish. Age group IV was poorly

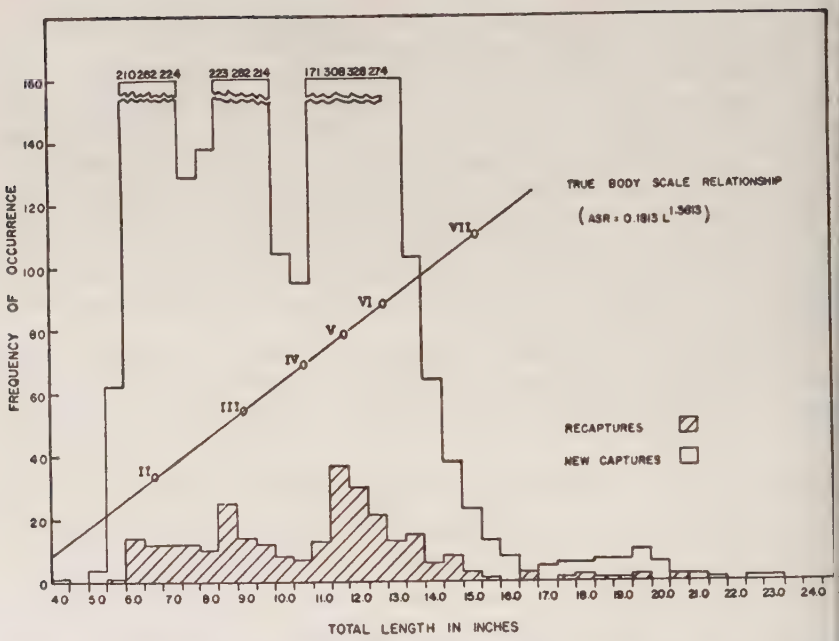

FIGURE 4.—Comparison of length frequency of new and recaptured largemouth bass caught by seine in Browns Lake. Diagonal line represents calculated growth rates of age groups.

represented in the scale samples and in the distribution. It is demonstrated clearly that the method of making growth calculations for this population of largemouth bass is a valid one.

POPULATION ESTIMATE

Largemouth bass used in the mark-and-recapture study were caught in a seine 2,000 feet long, 15 feet deep, and with 2 and 3-inch (stretched) mesh. Browns Lake is unusually well adapted for shoreline seining because most of the basin is less than 15 feet deep. The seine enclosed 13.3 to 28.9 acres, depending upon the configuration of the shoreline.

The population estimate was made in the fall for the following reasons: summer angling pressure declined with the end of the vacation season; the fish could be handled more easily at the lower water temperatures; recruitment did not affect the study since annual growth was practically complete; and most forms of submerged aquatic plants and filamentous algae do not interfere with seining in the fall.

The conditions necessary for a successful population estimate have been listed by Ricker (1948). There should be no recruitment during the time of the estimate or that corrections should be made for any recruit-

ment. The present estimate was completed within a short period of time; seining began on September 10 and was completed by September 30. There should also be no mortality of fish due to handling or marking. In the present study fish were impounded in the bag of the seine from which small groups were removed to be measured and marked, by excision of either the upper or lower lobe of the caudal fin or a portion of the second dorsal fin. Following the marking, fish were placed in a large tank and transported by boat to a central release point. During the 13 seine hauls only one dead fish was found prior to release and another was picked up on the shoreline. There was little reason to suspect any significant mortality.

The 3-week seining period was short enough to prevent fin regeneration of the clipped fins. Another factor that can harm population estimates is the differential availability of marked and unmarked fish. With the use of a seine the problem of net selectivity is avoided. The only conceivable difficulty lies in different abilities of marked and unmarked fish to escape the seine. Very few fish were observed jumping the cork line and, in a seining operation, fish do not actively seek escape until the seine is drawn into a small area.

To meet the problem of non-random distribution of marked fish and non-random location of seine hauls, a central release point was chosen from which the fish could make their way equally well to each of the three lobes of the lake. The seining effort was distributed throughout the lake to cover a large portion of the surface area. Thirteen seine hauls covered 232 acres of water with only a small amount of overlap (Fig. 1). One haul could be made in a day and usually three hauls were made each week. Generally the three hauls were arranged so that one was made in each of the three basins in any one week.

A further problem associated with fish-population estimates is unequal vulnerability of different sizes of fish. All fish 6 inches long were vulnerable to the seine. It is assumed that the seine caught large and small fish with equal success. By clipping the caudal and dorsal fins which are readily visible from either side of the fish, a minimum number of marked fish was overlooked by the crew.

Four methods are commonly used for calculating the population. Three are based on mark and recapture procedures and one on catch-effort statistics (Peterson, 1896; Schumacher and Eschmeyer, 1943; Schnable, 1938; and DeLury, 1947). All four have been used in this study to arrive at the best estimate of the population. The results of these estimates and the confidence limits or standard errors of estimates indicate good agreement among the four methods (Table 5).

The Peterson estimate, based on the recaptures of a known number of marked fish at large, can be made with each individual haul. The relatively small size of the sample and area sampled when compared with the whole population constitute a weakness. However, it is significant that in 3 of the last 5 hauls, when 10 percent or more of the population had been marked, the Peterson estimates were of the same magnitude, approx-

imately 20,000 fish. With this type of estimate it is also convenient to calculate confidence limits. The advantage of the Schumacher-Eschmeyer and the Schnabel methods is that all samples are included.

DeLury's (1947) method assumes that the total population can be told by a time-series plot of the catch per unit of effort against accumulated catch, when the fishing gear is the same and the effort removes a significant portion of the population in a short enough period to avoid bias from mortality and recruitment. Although the requirements listed by

TABLE 5.—*Estimates on the population of largemouth bass in Browns Lake, 1953*

Method of estimation	Total population	Confidence limits[1]	
		Minimum	Maximum
Peterson			
9th haul	20,882	14,712	27,012
10th haul	107,666	4,770	200,000
11th haul	20,338	12,838	27,838
12th haul	21,124	14,524	27,724
13th haul	14,038	11,748	16,328
Shumacher—Eschmeyer	19,780	[2]14,680	[2]24,920
Schnabel	21,980	.....	.....
DeLury	18,400	[3]10,900	[3]26,000

[1]Calculated from a normal approximation
[2]Standard error of the estimate, two standard errors
[3]Standard error of the estimate, one standard error

DeLury were met only partially, the data were sufficient to permit calculation of a regression line which gave an estimate of a total population of 18,400 largemouth bass.

The existence of any significant failure to meet the necessary assumptions in the mark-and-recapture estimates has yet to be determined. The first approach toward this question, a comparison of the length frequencies of the newly caught fish with the recaptures, showed little difference in size distribution between the two groups (Fig. 4).

Mortality among the small marked fish less than 8 inches long is suggested by the recovery of a few dead ones. A comparison of the percentage recapture of small fish with percentage recapture of the large ones showed approximately 10 percent more large fish than small ones among the recaptures. This discrepancy suggests that the mark-and-recapture estimates may be somewhat too high.

Fish from each of the three basins were given a different mark and all were released at a central point. Since each basin contained marked fish from another basin, it is apparent that considerable mixing was taking place (Table 6). By dividing a lake in Michigan into halves (Cooper, 1952) detected some homing, but he finally concluded that the tendency to catch fish more often in the "home half" could have been largely a function of distance to the nets rather than homing. A more detailed exami-

nation of random distribution of marked fish within three-lobed Browns Lake was made through a chi-square test of the assumption that random mixing was taking place (Table 6). The chi-square values indicated that random mixing was not completely attained. This situation does not, however, cast serious doubt upon the estimates.

Mixing was considerable and the seine hauls were sufficiently well distributed about the basins to avoid any serious bias toward any one group of homing fish. It does appear that in the future it would be profitable to estimate the population of each of the three basins individually by having a separate mark and central release point in each basin.

TABLE 6.—*Basin location of seine hauls, marks at large and distribution of recaptures of largemouth bass, Browns Lake, 1953*

Haul number	Mark of basin where haul was made	Top of caudal fin		Bottom of caudal fin		Dorsal fin		Chi square test of random mixing
		At large	Recaptures	At large	Recaptures	At large	Recaptures	
1.....	Caudal fin, top	.....	..	.....	..	...	..	.....
2.....	Caudal fin, bottom	292	1	.....	..	...	..	.....
3.....	Dorsal fin	292	1	543	..	...	..	1.86
4.....	Caudal fin, bottom	292	..	543	..	194	..	.....
5.....	Caudal fin, top	292	2	686	4	194	..	1.24
6.....	Caudal fin, bottom	660	..	686	3	194	..	3.92
7.....	Caudal fin, top	660	21	772	8	194	3	8.50
8.....	Caudal fin, bottom	816	..	772	11	194	..	13.2
9.....	Caudal fin, top	816	15	996	19	194	6	1.27
10.....	Dorsal fin	1,192	1	996	2	415	2	7.23
11.....	Dorsal fin	1,192	11	996	16	708	16	16.4
12.....	Caudal fin, bottom	1,192	3	996	30	708	1	43.6
13.....	Caudal fin, top	1,192	99	1,210	10	708	..	127.8

DENSITY OF POPULATION

The various methods of making the population estimate on the largemouth bass gave values ranging from 18,400 to 21,980 fish. Of these the Schnabel method with a population of 21,980 fish (Table 7) was accepted as probably the most dependable.

In 396-acre Browns Lake there were 55.5 fish 6 inches long and larger, per acre, with an estimated weight of 33.3 pounds per acre. Bennett (1951), in repeated drainings at 2-year intervals of Ridge Lake, Illinois, reported 48.2, 39.6, 31.5, and 50.4 pounds per acre. He stated, "This (50 pounds per acre) approaches the maximum carrying capacity for largemouth bass." Even without any knowledge of local conditions, it is to be expected that Bennett would encounter a greater population of fish because he collected fish of all sizes by draining the pond.

Cooper (1952) estimated the population of largemouth bass by trap nets in Sugarloaf Lake in Southern Michigan. There the density was 6.6 pounds per acre, much smaller than in Browns Lake. Gerking (1953), though admitting the inadequacy of his sampling by cylindrical wire

traps, estimated the largemouth bass population to be between 3.7 and 8.7 pounds per acre in Gordy Lake, Indiana. In California, Wohlschlag (1953) estimated the population of largemouth bass present in a carp-infested, 900-acre reservoir. At the summer drawdown—about 450 acres—it was estimated by "mark-and-recapture" methods that the population was 36 fish or 9.2 pounds per acre.

The Browns Lake results are more nearly comparable to Bennett's data than to any of the others. Although age group O was omitted from the estimate, the density of fish was two-thirds that described by Bennett as the maximum carrying capaciy of largemouth bass. Despite heavy angling Browns Lake still held a large population of largemouth bass.

TABLE 7.—*Summary of seining results and a Schnabel estimate of the population of largemouth bass for 1953 in Browns Lake*

[Symbols taken from Schnabel (1938)]

Time interval	Marks at large (B)	Fish captured (A)	Number recaptures (C)	AB	AB/C	Cumulative ΣAB	Cumulative ΣC	Cumulative ΣAB/C
1	....	292	...	.....	.....	.....	...	.....
2	292	544	1	158,848	158,848	158,848	1	158,848
3	835	195	1	162,835	162,835	321,673	2	160,836
4	1029	143	...	147,147	.....	468,820	2	234,410
5	1172	374	6	438,328	73,055	907,148	8	113,394
6	1540	89	3	137,060	45,687	1,044,208	11	94,928
7	1626	188	32	305,688	9,553	1,349,896	43	31,393
8	1782	235	11	418,770	38,070	1,768,666	54	32,753
9	2006	416	40	834,496	20,862	2,603,162	94	27,693
10	2382	226	5	538,332	107,666	3,141,494	99	31,732
11	2603	336	43	874,608	20,338	4,016,102	142	28,282
12	2896	248	34	718,208	21,124	4,734,310	176	26,899
13	3110	492	109	1,530,120	14,038	6,264,430	285	21,980

EXPLOITATION AND MORTALITY RATE

A rough estimate of the rate of exploitation by anglers is obtained by comparing the number of fish creeled in the summer to the population computed in the fall. From creel-census data it was estimated that 2,671 largemouth bass were caught. The population in the fall was estimated at 21,980 fish. Thus, the angler harvest in a single season was 12.1 percent of the estimated fall population.

The total mortality rate can be estimated from the age composition of the population (Jackson, 1939). From the frequency distribution of all age-groups in the population which were completely vulnerable to anglers, the average annual mortality rate for the largemouth bass for the years 1943 to 1952 was computed to be 24 percent. Such an estimate assumes that the recruitment, though unequal from year to year, tends to balance with the carrying capacity of the water over a period of years.

When the total mortality is only 24 percent and the angling mortality about 12 percent, future maintenance of the largemouth bass population

in Browns Lake should be secure, for many ocean and fresh water species experience much greater attrition. It is concluded that relaxed regulations are desirable, for they permit greater utilization of the largemouth bass from a large population.

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THE LAKE TROUT OF COLD STREAM POND, ENFIELD, MAINE [1]

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ABSTRACT

Lake trout, *Cristivomer namaycush* (Walbaum), were netted in Cold Stream Pond, Enfield, Maine during the spawning seasons of 1951, 1952, 1953. The fish were weighed, measured and tagged with monel-metal jaw tags, and scale samples were secured for age determinations. A creel census, conducted during the fishing seasons of 1952 and 1953, contributed additional age and growth information and tag recoveries.

Two hundred ten lake trout were tagged at the Webb Cove spawning area in October 1951, and 266 in the same area in October 1952. During the netting operations of 1952, 357 lake trout were taken including 91 fish tagged from the 1951 spawning population. In October 1953, similar netting operations yielded a catch of 233 fish including 40 tagged fish from the 1951 spawning population and 57 tagged fish from the 1952 spawning population. Recovery of tagged fish showed lake-wide distribution of the Webb Cove spawning population. Unsuccessful attempts to gillnet spawning fish on other suitable spawning areas support the assumption that the majority of lake trout in Cold Stream Pond utilize Webb Cove for spawning.

Four hundred fifteen lake trout were creeled during the fishing season of 1952: 36 were recaptures of fish tagged in 1951. Four hundred eighty-nine lake trout creeled in 1953 included 125 tagged fish: 35 and 90 recaptures were tag recoveries from the 1951 and 1952 spawning populations respectively.

The total length of the spawning fish were 15.7 to 36.5 inches. Most of the spawning migrations in the 3–year study period were made up of fish with total lengths of 18.1 to 20.0 inches in age groups VI and VII. Only 1 fish with a total length less than 16.3 inches and 32 fish less than 17.1 inches were taken in the 3–year period.

The majority of the creeled fish in 1952 and 1953 were included in a total-length range of 17.1 to 19.0 inches in age groups V, VI, and VII. About 30 percent of the total number of fish creeled in 1952 and 1953 were immature. A length regulation of 14 inches controls the minimum size of fish that anglers take.

Male lake trout in Cold Stream Pond mature at age V (17.2 inches) and females at age VI (18.1 inches). One and 2-year growth increment curves show a definite retardation of growth as a result of jaw tags. In some instances annuli were not laid down in the 1- and 2-year periods that tagged fish were at large.

A high rate of exploitation is indicated by creel census data. Population estimates revealed that fishing success depends on a relatively small population of mature fish.

INTRODUCTION

Cold Stream Pond is a typical Maine oligotrophic lake with an area of 3,628 acres and a maximum depth of 112 feet. Thermal stratification occurs during the summer when the thermocline forms at a depth of about

[1] Dingell-Johnson Project F-3-R and F-5-R.

30 feet. Surface temperatures seldom exceed 70° F., while temperatures in the hypolimnion average about 51° F. Dissolved oxygen content ranges from 8.8 p.p.m. at the surface to 7.4 p.p.m. in the hypolimnion.

The primary objectives of the lake-trout study were to determine the age and size composition of the population, the frequency and time of spawning, the size at maturity, mortality rates, population estimates, and the influence of these factors on angler's catches.

The Cold Stream Pond lake-trout investigation began in October, 1951 with the netting of spawning fish, and was continued in October, 1952 and 1953. A creel census was conducted from April 22 to August 23, 1952, and from April 15 to September 6, 1953 to obtain data concerning the age and size of lake trout entering the sports fishery and to provide tagged-fish recoveries for population and exploitation estimates.

The only known spawning area utilized by lake trout is located on the southeast shore in Webb Cove (Fig. 1). This shore area is windswept for the most part during the summer and fall months, leaving the rock-bottomed area free of mud and sand. The area utilized by spawning lake trout included ¾ to 1 mile of shore line.

Game species present include lake trout, landlocked salmon, *Salmo salar* (Linnaeus), eastern brook trout, *Salvelinus fontinalis* (Mitchill), white perch, *Morone americana* (Gmelin), and chain pickerel, *Esox niger* (LeSueur). The chief forage fish is the American smelt, *Osmerus mordax* (Mitchill).

Other species of fish known to be present are:

American eel	*Anguilla bostoniensis*
White sucker	*Catostomus commersoni*
Redbelly dace	*Chrosomus* species
Golden shiner	*Notemigonus crysoleucas*
Fallfish	*Semotilus corporalis*
Creek chub	*Semotilus atromaculatus*
Common shiner	*Notropis cornutus*
Lake chub	*Couesius plumbeus*
Blacknose dace	*Rhinichthys cataractae*
Brown bullhead	*Ameiurus nebulosus*
Banded killifish	*Fundulus diaphanus*
Ninespined stickleback	*Pungitius pungitius*
Yellow perch	*Perca flavescens*
Yellowbelly sunfish	*Lepomis auritus*
Pumpkinseed	*Lepomis gibbosus*
Fresh-water sculpin	*Cottus cognatus*

Fish Collections

Fish collections during the 1951 spawning period were obtained using the methods and facilities of the Maine Hatchery Division. The Hatchery Division has obtained eggs annually at Webb Cove in Cold Stream Pond for at least 13 years. Spawning fish were collected with three 100-foot sweep seines. One end of each net was secured to the shore with the other end extended into the lake for a distance of about 30 feet. As the fish

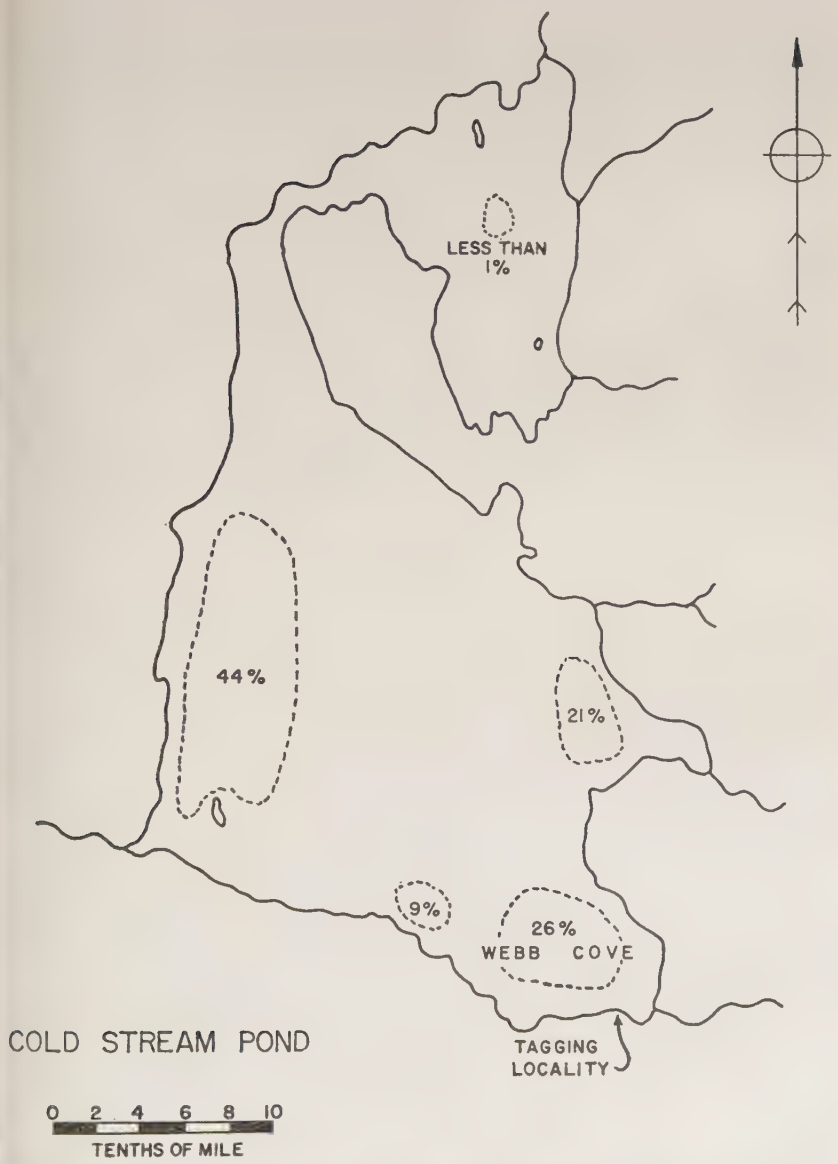

FIGURE 1.—Localities and percentages of tagged fish caught by fishermen in 1952-1953.

moved along the shore in search of suitable spawning area they entered the extended nets. Each seine was closed by drawing in the extended end, which formed a pocket that prevented the fish from leaving the net and

made it possible to dipnet the trapped fish. The seines were tended once or twice an hour throughout the night, depending on the intensity of the run of fish. As the fish were captured they were separated according to sex and placed in holding pens which had compartments to facilitate separation of males and females, spawned and unspawned.

A 450-foot experimental gill net was used in 1952 and 1953 in addition to the sweep seines. The net was set across a small cove with both ends secured to shore. Large numbers of fish were taken in a short time. Running the net every 10 to 15 minutes prevented injury to the fish which were placed in a live-car anchored near the net. At the completion of each night's operations, the live-car was towed to the holding pens and the fish distributed as in 1951. Collecting fish by gill net was more effective than collecting by sweep seine. In 1952 approximately 60 percent of the total number of fish were taken by gill net. Actual netting time by gillnetting was approximately 4 hours per night for 4 nights as compared to all-night netting for 7 nights with 3 sweep seines. In 1953 approximately 90 percent of the total catch was taken by gillnetting. Observations and gillnetting revealed large numbers of fish in the deeper water.

Tagging Operations

Tagging operations began when sufficient numbers of fish were present in the holding pens. Urethane (17 grams to 1 gallon of water) was used throughout the investigation to facilitate handling and tagging. Anesthetized fish were checked for previous tags, weighed to the nearest ounce, and measured (total length and fork length) to the nearest tenth of an inch. A scale sample was removed from the right side just below the dorsal fin. If the fish was not already tagged, a flat monel-metal circular jaw tag was attached around the right lower jaw (Rounsefell and Kask, 1945). The tags were stamped Me. I. F. & G., and with an identifying number.

Tagged fish were placed in a large pool in the shallow water along the shore. A careful check was maintained for 7 to 10 days to determine tagging or handling mortality. No mortality was noted in the holding pool during the 3-year study. All fish, with few exceptions, were not tagged until after they had been stripped. Two tagged fish were found dead near the outlet in the fall of 1951 heavily fungused about the head and from the dorsal fin posteriorly. It would be impossible to determine whether the fish had died as a result of the stripping or tagging operation, or both.

Tag Recoveries.—Tags were recovered from the fish returning to the Webb Cove spawning area in 1952 and 1953, and by checking anglers' creels in the same years. Especially noteworthy is the high percentage of recapture and recovery. Recoveries from the October 1951 tagging of 210 lake trout in Cold Stream Pond were:

Year recaptured	*Sport fishing*	*Spawning migration*	*Percentage recaptured*
1952	36	91	62
1953	35	40	44

Totals were adjusted to eliminate 2 fish that were found dead in the outlet stream and 3 fish that had left the lake via the outlet shortly after tagging, and were reduced each year by numbers removed through sport fishing. Tags recaptured for a second time were counted in computing final percentages.

Recoveries from the October 1952 tagging of 266 lake trout were:

Year recaptured	*Sport fishing*	*Spawning migration*	*Percentage recaptured*
1953	90	57	55

Tagged fish accounted for 18 percent of the total catch of lake trout in the 2-year census period, and fishermen reported a good distribution of tagged fish throughout the lake. Thirty percent of the fishermen reported the location of their tagged fish. Forty-four percent of these fish were caught more than 2 miles from Webb Cove, while 26 percent were caught in Webb Cove, the original location of tagging. Five tagged fish were reported caught in the "upper lake", a distance of about 6 miles from the original tagging station.

Errors in the use of tag recoveries may have been introduced by unreported tags, and the vulnerability of tagged fish to capture. The effects of these errors have not been evaluated. Some spawning fish had lost their tags. In 1953 five such fish were observed in the total of 233 captured. The high percentage of recovery may help to minimize the effects of the usual tagging study errors.

Creel census data are rarely complete. It is believed that more than 90 percent of the anglers were contacted during the study. Sportsmen were informed of the objectives of the project by radio, newspaper, notices, speaking engagements, and many personal contacts. Biologists and creel census clerks were at the lake during fishing periods.

Effects of Tagging.—Many studies have shown that jaw tags probably inhibit the growth of fish (Smith, Krefting, and Butler, 1952). Tag recoveries on the spawning grounds each October provided a growth record of tagged fish over a 1- and 2-year period. Comparisons were made with fish taken in the creel census to determine whether retarded growth of tagged fish were characteristic only during the spawning periods.

Fish tagged with a circular-type strap jaw tag do not grow at a normal rate, Figure 2. In some instances tagged fish failed to show annuli in the 1- and 2-year periods at liberty, and growth in these cases was negligible. The condition of the recaptured fish did not appear to differ from that of non-tagged fish, and no irritation was found around the mouth as a result of the tag. In general, males grew faster and appeared to be in better condition than females. Creel census figures on the return of tagged fish showed similarly that nearly all tagged fish had grown at a sub-normal rate.

Spawning Habits

Place of spawning.—The area selected for spawning is most generally a wind-swept shore where the rocky bottom is kept free of mud and sand

by wave action and water currents. The size and depth of the lake usually determine the amount of suitable spawning area. The larger, deeper lakes, because of the greater currents and wave action, contain greater areas of bottom free of mud and sand.

At Cold Stream Pond, lake trout have been observed spawning in water depths of 6 inches to 10 feet. Royce (1951) reported that ripe lake trout in Seneca Lake, New York, were captured in depths to 200 feet over suitable spawning bottom. There is little evidence that lake trout select spring seepage areas for spawning, as temperatures taken at various locations in Webb Cove failed to reveal the presence of springs. The same results were reported in New York State (Royce 1951).

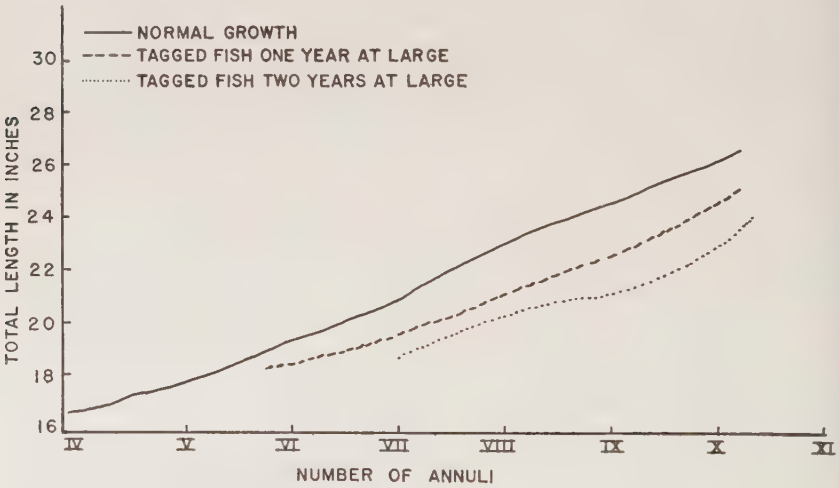

FIGURE 2.—Comparison of normal growth with growth of tagged fish at large one year and two years.

Time and duration of spawning.—Hatchery Division records for the past 13 years show that the spawning run is usually from October 9 to 20. Males precede the females and are usually seen in the early morning or late afternoon and evening busily cleaning silt from the rock bottom. Silt removal is accomplished by the fish swimming close to the bottom and moving the rocks and stones with their tails. Two to 5 days after the males first appear on the spawning grounds the females arrive. Spawning begins when water temperatures drop below 50°F., or nearly coincidental with the fall turnover of the lake.

The length of the spawning migration varies from year to year with an average length of 12 days as measured over a 13 year period. The peak of the run comes about 5 days after the females first appear in the area.

Sexual dimorphism and sex ratio.—The male lake trout has a wide,

black band running horizontally along its sides that can be observed underwater. The snout of the male is somewhat more pointed than the female. Females are identified by the bright strawberry coloration and swelling about the vent. The ratios of males to females taken during the spawning migration were: 1951, 3.3 to 1; 1952, 3.1 to 1; 1953, 3.0 to 1.

Egg predation.—Stomach analysis of lake trout, eels and white suckers revealed lake trout eggs. Even when the eggs were deposited over ideal bottom area eels were observed burrowing into the crevices between the rocks. Although suckers taken on the spawning beds contain lake trout eggs in their stomachs, it is doubtful that they would take any great numbers of properly lodged eggs.

Creel Census

A creel census was conducted on Cold Stream Pond during the 1952 and 1953 fishing seasons. Biologists were present daily on the lake throughout the fishing season from April 20 to August 23, 1952. The census was discontinued after August 23 because of the almost total lack of fishermen. In 1953 a great decrease in weekday fishermen by mid-June prompted a discontinuation of the weekday census and creel checks were continued only on weekends for the remainder of the fishing season.

Table 1.—*Summary of creel census data for 1952 and 1953 seasons*

Item	1952	1953	Total
Number of fishermen	1,529	1,406	2,935
Number of lines fished	1,730	1,668	3,398
Total hours fished	4,232	4,794	9,026
Total line hours fished	10,930	8,905	19,835
Total fishermen hours fished	9,894	7,667	17,561
Number of fish taken:			
Lake trout	415	489	904
Landlocked salmon	123	342	465
Eastern brook trout	4	1	5
Chain pickerel	11	3	14
White perch	12	11	23
Average catch per fisherman	0.4	0.6	0.5
Average catch per line	0.3	0.5	0.4

No attempts were made to calculate an average fishing day for the periods in 1952 and 1953 when the census was discontinued. Data for both fishing seasons include only empirical information. In the 2-year creel sensus 2,935 fishermen fished 3,398 lines for a total of 19,835 line hours and caught 1,411 fish. The average catch per fisherman was 0.5 fish and the average catch per line was 0.4 fish. Table 1 summarizes the data collected during the 2-year census. All game fish were included in the catch statistics.

Analysis of fishing methods.—Two methods are employed in taking lake trout in Cold Stream Pond: trolling and "plug" or still fishing. Troll-

ing is by far the more preferred of the two methods, but plug fishing is growing in popularity each year. Regulations prohibiting plug or still fishing as a harmful practice have been enforced on various waters in Maine. Prompted by this action special attention was given to the success of the two fishing methods as used at Cold Stream Pond.

Twenty-three percent of those who fished Cold Stream Pond in 1952 and 1953 were plug fishermen. This minority group caught 32 percent of the total catch of lake trout in the 2-year period. This greater success (Table 2) is probably the result of the lake trout congregating during the summer months in the deep, cool waters bordering a shoal area. Knowing these areas the plug or still fisherman concentrate their efforts on them. An angler trolling may pass through these areas in a few seconds. Available information indicates that plug or still fishing for lake trout in Cold Stream Pond is more efficient than trolling. Since a greater number of anglers troll, trolling accounts for the capture of twice as many fish as plug or still fishing.

TABLE 2.—*Comparative statistics of the plug and troll fisheries*

Method	Number of fishermen	Number of lines	Total line hours fished	Number of fish caught	Percentage of successful parties
Plug	696	1,043	4,394	285	23
Troll	2,273	2,399	15,406	614	36

AGE AND GROWTH

Ages of lake trout were determined from the scales and are expressed in number of annuli. Average lengths and weights were calculated from empirical measurements. Age determinations of the scales of 617 mature lake trout netted during their spawning migrations at Webb Cove showed that these fish reach sexual maturity sometime during the sixth and seventh growing season. The average male matures at 17.2 inches (Age V); the female at 18.1 inches (Age VI).

Tables 3 and 4 show frequency distributions of 617 and 657 lake trout taken on the spawning grounds and caught during the fishing season. The 18.1 to 20.0 inch size class contributed the bulk of the spawning population while the 17.1 to 19.0 inch size class contributed the bulk of the creel-census catch. Fish taken on the spawning runs ranged in total length from 15.7 inches to 36.5 inches. Only one fish below a total length of 16.3 inches and 32 fish below 17.1 inches were taken as compared to approximately 30 percent of the total 2-year creeled catch composed of fish 14.0 to 17.0 inches.

Since all fish taken during the spawning migrations were captured at approximately the same date each year, a good opportunity was afforded to obtain average lengths and weights for the various age groups represented in the spawning populations. Table 5 summarizes these data and shows

TABLE 3.—*Frequency distribution of lake trout taken on the spawning runs of Cold Stream Pond 1951, 1952 and 1953*

Size class (inches)	Age groups									Number of fish	Percentage of total
	IV	V	VI	VII	VIII	IX	X	XI	XII		
[1]16.0–17.0	15	17	...	...	...	...	...	...	...	32	5.2
17.1–18.0	3	61	12	...	...	...	...	...	...	76	12.3
18.1–19.0	...	44	91	1	...	...	...	...	...	136	22.0
19.1–20.0	...	5	102	23	...	...	...	...	...	130	21.1
20.1–21.0	...	...	40	51	1	...	...	...	...	92	14.9
21.1–22.0	...	...	2	36	16	1	...	...	...	55	8.9
22.1–23.0	...	...	...	...	39	4	...	...	...	43	7.0
23.1–24.0	...	...	...	...	20	5	...	...	...	25	4.0
24.1–25.0	...	...	...	...	3	5	1	...	...	9	1.4
25.1–26.0	...	...	...	...	...	3	...	...	...	3	0.5
26.1–27.0	...	...	...	...	...	3	...	...	...	3	0.5
27.1–28.0	...	...	...	...	...	1	...	...	...	1	0.2
28.1–29.0	...	...	...	...	...	...	...	1	...	1	0.2
30.1–36.0	...	...	...	...	...	...	3	5	3	11	1.8
Totals	18	127	247	111	79	22	4	6	3	617	100.0

[1]A single fish 15.7 inches is included

that age-group VI was the best represented of any single age group, and age-groups V, VI and VII made up (80 percent) of all age groups represented.

The creel census data for age and growth are presented in Table 6. The bulk of the catch is composed of age-groups V, VI and VII. Tables 5 and 6 include only fish through age-group IX. Table 6 denotes that the average growth for all age groups ranged from 0.9 inches to 2.1 inches. Average weight gain ranged from 0.21 pounds to 1.15 pounds for all age groups. The average gain in length for tagged fish varied from 0.10 to 0.72 inches and the weight from 0.07 pounds to 0.5 pounds annually. The tagged fish demonstrated considerably less growth.

TABLE 4.—*Frequency distribution of lake trout taken in the creel census at Cold Stream Pond in 1952 and 1953*

Size class (inches)	Age groups							Number of fish	Percentage of total
	IV	V	VI	VII	VIII	IX	X		
14.0–15.0	38	9	...	...	...	...	...	47	7.1
15.1–16.0	33	36	...	...	...	...	...	69	10.5
16.1–17.0	3	69	1	...	...	...	...	73	11.1
17.1–18.0	...	76	34	...	...	...	...	110	16.7
18.1–19.0	...	16	111	68	...	...	...	195	29.7
19.1–20.0	...	...	80	15	1	...	...	96	14.6
20.1–21.0	...	...	9	25	2	...	...	36	5.5
21.1–22.0	...	...	...	9	10	...	...	19	2.9
22.1–23.0	...	...	...	3	3	...	...	6	0.9
24.1–25.0	...	...	...	...	...	3	...	3	0.5
25.1–26.0	...	...	...	...	...	...	2	2	0.3
27.1–28.0	...	...	...	...	...	...	1	1	0.2
Totals	74	206	235	120	16	3	3	657	100.0

TABLE 5.—*Average total lengths (inches) and weights (pounds) of lake trout through age groups IX taken on the spawning grounds of Cold Stream Pond in 1951, 1952 and 1953*

Age group	Number of fish	Average and range		Percentage of total
		Total length	Weight	
IV	18	16.6 (15.7–17.7)	1.33 (1.0–1.7)	3.0
V	127	17.5 (16.1–18.2)	1.54 (1.1–1.8)	21.0
VI	247	19.2 (17.8–22.0)	1.93 (1.4–3.0)	40.9
VII	111	20.6 (19.1–23.9)	2.54 (1.8–3.9)	18.4
VIII	79	22.7 (20.1–24.3)	3.31 (2.2–4.6)	13.1
IX	22	24.2 (21.9–27.9)	4.46 (3.0–7.4)	3.6

TABLE 6.—*Average lengths (inches) and weights (pounds) of age groups of lake trout through age group IX taken in the creel census at Cold Stream Pond in 1952 and 1953*

Age group	Number of fish	Average and range		Percentage of total
		Total length	Weight	
IV	77	15.1 (13.6–16.8)	1.12 (0.8–1.9)	11.8
V	203	17.0 (14.4–18.9)	1.55 (0.9–2.1)	31.0
VI	235	18.9 (17.2–20.8)	2.15 (1.8–3.0)	35.9
VII	120	20.1 (18.1–21.6)	2.64 (2.0–3.3)	18.3
VIII	16	21.9 (19.0–22.4)	3.35 (2.2–4.0)	2.5
IX	3	23.5 (21.5–24.9)	4.46 (3.6–5.5)	0.5

The growth rate of lake trout in Cold Stream Pond compared with the growth in Moosehead Lake and Branch Pond, Maine, (Cooper, 1946).

	Age group					
Total length (inches)	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*
Moosehead	11.0	14.6	16.1	18.4	21.1	22.4
Branch Pond	15.4	18.1	20.2	22.7	25.9	.....
Cold Stream	16.6	17.5	19.2	20.6	22.7	24.2
Weight (pounds)						
Moosehead	0.4	1.0	1.3	2.0	3.3	4.1
Branch Pond	1.4	2.1	3.3	4.6	8.4	....
Cold Stream	1.3	1.5	1.9	2.5	3.3	4.5

Cold Stream Pond lake trout grow somewhat faster than those in Moosehead Lake and grow slower than the lake trout in Branch Pond. Work in

New York State (Royce, 1951), and Canada (Martin, 1952), showed similar variations of growth rate.

Mortality and Population Estimates

Mortality estimates.—The total annual mortality rate may be estimated by substituting representative data from Tables 3 and 4 in the Jackson formula (Ricker, 1948). The age distribution determined from scale readings of fish taken in the creels and on the spawning runs are as follows: Age group VI, 482; age group VII, 231; age group VIII, 95; age group IX, 25. Age groups IV and V had not all attained sexual maturity and were therefore not sampled representatively on the spawning grounds. The estimate of total mortality then must be based on fish of age group VI and older. By the Jackson method then the total annual survival equals:

$$\frac{231 + 95 + 25}{482 + 231 + 95} \times 100 = \frac{351}{808} = 43 \text{ percent and}$$

Total annual mortality $100 - 43 = 57$ percent

A part of the total annual mortality is the result of exploitation and can be calculated (Ricker, 1948) by dividing the number of tagged fish at large into the number recaptured in the fishery. Before this is done consideration should be given to the error involved in the rate at which fish lost their tags. In 1952 and 1953, fish checked on the spawning runs were found to lose tags at a rate of 3 percent. It should be correct to assume that 3 percent of the 471 tagged fish at large would have lost their tags before recapture. With this deduction considered, there were assumed to be 457 tagged fish at large. One hundred and sixty-one recaptures were taken in the fishery from a total of 457 tagged fish at large for a rate of exploitation of 35 percent (161/457). The expectation of natural death becomes: $57 - 35 = 22$ percent.

Population estimates.—Estimates of populations were made on spawning populations as well as lake populations using the Peterson Formula. The estimates of range of error are derived for the 5-percent limit of probability.

Spawning populations.—In October, 1952, 169 tagged fish were assumed to be at large in the lake, since fishing mortality had accounted for 36 of the 205 tagged fish during the fishing season of 1952. In netting operations of 1952 a total of 357 lake trout were netted; 91 were recaptures from the 1951 tagging operations, thus:

$$P = \frac{AB}{C} = \frac{(357)\ (169)}{91} = 663\ (513 - 814)$$

P = estimate of population
A = total number of fish taken
B = number of tagged fish at large
C = number of recaptures

In October, 1953, a total of 310 tagged fish was assumed to be at large in the lake after deducting fishing mortality during the fishing seasons of 1952 and 1953. In netting operations of 1953, a total of 233 fish was netted; 97 were recaptures; 40 were from the 1951 population and 57 from 1952.

$$P = \frac{AB}{C} = \frac{(233)\ (310)}{97} = 745\ (611 - 907)$$

The known discrepancy in the above estimates stems from the fact that yearly expected natural death rate and loss of tags are not deducted from the total numbers of tagged fish assumed to be at large. With an annual expected death rate of 22 percent and a 3 percent rate of tag loss and using the same formula as above, the estimated spawning population at Webb Cove in 1952 and 1953 becomes, 391 (363-573) and 397 (327-485) respectively.

Lake populations.—Tagging operations sampled only those fish with a total length of 16.3 inches and above, any estimates of the lake population will include only fish within this total length range.

In 1952, the lake population was estimated on the tag recoveries from the creel census during April to August. During that period 36 tagged fish were recaptured out of a total catch of 415 lake trout. Since 5 of the original 210 tagged fish were known to have died or left the lake via the outlet stream, 205 tagged fish were assumed to be at large at the beginning of the 1952 fishing season. If it is assumed however, that the natural death expectancy is at a constant rate throughout each month of the year, then it would be correct to expect that the natural rate of death per month is 2 percent. Thus the natural death rate from October, 1951 to April 1952 (6 months) would be 12 percent. After deducting the natural death rate expectancy in a 6-month period and a 1.5 percent rate of tag loss for the same period there were assumed to be 178 tagged fish at large at the beginning of the 1952 fishing season, thus:

$$P = \frac{AB}{C} = \frac{(415)\ (178)}{36} = 2{,}030\ (1{,}485 - 2{,}840)$$

In 1953, the lake population was estimated from 125 tagged fish taken in the creels which included 35 fish from the 1951 population and 90 fish from those tagged in 1952. The total catch of lake trout in 1953 was 489. Since 36 of the original 205 tagged fish of 1951 were caught in 1952, an annual expected death rate of 22 percent, and a 3 percent annual rate of tag loss are deducted, it was assumed that 98 of the 1951 tagged fish were at large at the start of the 1953 fishing season. Using the same assumption for expectancy of natural death rate and rate of tag loss over a six-month period as in 1952, it was assumed that 230 of the 1952 tagged fish were at large at the beginning of the 1953 fishing season, or a total of 328 fish, thus:

$$P = \frac{AB}{C} = \frac{(489)\ (328)}{125} = 1{,}282\ (1{,}078 - 1{,}522)$$

The above population estimates, especially on the lake populations, are subject to the same systematic errors. It must be assumed that the effects of tagging and handling on survival are negligible, and the ratio of tagged to untagged fish in the creel represented the true ratio of the lake population. The greatest possibility of error probably is in the number of tagged fish returns. Some fishermen possibly did not report tag recoveries. The number of tagged fish reported may be somewhat low, and the population estimates correspondingly high.

Appraisal of the Cold Stream Pond Lake Trout Fishery

Fishing success was somewhat better in Cold Stream Pond than in other Maine lakes where creel-census work has been conducted. The average catch per fisherman was 0.5 and the average catch per line was 0.4. The bulk of the 2-year angling catch was made up of fish ranging in total length from 17.1 inches to 19.0 inches (age-groups V, VI, VII).

Male lake trout matured at an average length of 17.2 inches (age V), and females matured at an average length of 18.1 inches (age VI). A minimum legal length of 14.0 inches resulted in an annual creel composed of 30 percent immature fish.

In 1953 angling accounted for 20 percent of the fish tagged in 1951 and 34 percent of the fish tagged in 1952. Spawning fish recaptures of 1953 yielded 30 percent of the 1951 tags and 32 percent of fish tagged in 1952. In the 2 years of creel census a tag return of 34 percent of both tagging years was obtained, while a 40-percent return of all tags was obtained on the spawning migrations of 1952 and 1953.

The circular-type jaw tags produce certain adverse effects. Tagged fish, at liberty 1 and 2 years, grew at a subnormal rate and in some instances even lost weight. In no instance was there erosion or irritation about the jaw as a result of the tag. A small percentage of fish lost tags: 5 such fish were identified in the 1953 spawning migrations when 233 fish were examined.

Observations of the annual spawning migrations showed that spawning lake trout in Cold Stream Pond prefer the rock-bound, wind-swept shores of Webb Cove. Spawning activities commence each October with the approach of the fall lake turnover when water temperatures range from 50°F. to 45°F. The length of the spawning period is about 12 days with the peak of the run coming about five days after the appearance of females in the area.

Fish taken on the spawning grounds ranged in total length of 15.7 inches to 36.5 inches with only 32 fish below a total length of 17.1 inches taken in the three year netting period. The bulk of the fish contributing to the annual spawning population was made up of fish in the 18.1–20.0 inch size class, age VI.

The rate of exploitation was estimated at 35 percent. The expected nat-

ural death rate was 22 percent. The Cold Stream Pond lake trout fishery is dependent on a small population of fish exposed to a high rate of exploitation. An annual catch made up of some 30 percent immature fish, further endangers the spawning potential and future stocks of the lake fishery.

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SEASONAL VARIATION IN THE INCIDENCE OF LYMPHOCYSTIS IN THE WHITE CRAPPIE FROM THE NIANGUA ARM OF THE LAKE OF THE OZARKS, MISSOURI [1]

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ABSTRACT

Seasonal variation in the incidence of diseases or parasites in natural populations of fishes has not been documented. Seasonal variation in the incidence of lymphocystis in the white crappie, *Pomoxis annularis,* was determined from 5,906 fish collected in 1950–1951 and 1,593 fish collected during October 1952 through 1955. The incidence of the disease was greatest in July (10.7 percent), decreased in October (1.7 percent) and increased in November (6.9 percent). Over winter the incidence of the disease gradually decreased and reached a low in April (1.4 percent) after which it increased again. The tumors occurred on all parts of the body and fins but over 60 percent on the caudal fin. The disease was more prevalent in fish under 6.7 inches than in larger ones. In 1950–1951, 97 percent of the infected fish were less than 6.7 inches long. The 1949 year class was abundant during this study and its members carried the disease for a period of 3 years. The disease does not appear to be lethal to the white crappie; however, infected fish weighed 3 to 5 percent less than sound fish of the same length. Only one other fish, a walleye, was found to be infected.

INTRODUCTION

The seasonal variation in the incidence of diseases or parasites in natural populations of fishes is a little known aspect of piscine biology. The literature contains generalizations to the effect that the incidence of diseases or parasites is high in the summer and low in the winter, but these generalizations are usually not documented.

In general, parasitism in fishes has been attacked in three ways. First, summer surveys have been made of a lake or lakes within a region to determine the kinds and numbers of parasites which are harbored by all species of fishes. The incidence of infection is expressed as a percentage of the total number of fishes examined harboring one or more species of parasites. This type of study is best exemplified by the works of Bangham and Hunter (1939), Bangham (1946), Essex and Hunter (1926), and Fischthal (1947). Incidences of infection were reported to vary from 39 to 96 percent.

Secondly, a species of fish has been collected once or several times during a year, or over a period of years, and the annual incidence of a particular

[1]Contribution from the Missouri Cooprative Wildlife Research Unit; U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and the University of Missouri cooperating.

parasite determined. Lawler (1954) has done this for the troutperch in Henning Lake, Manitoba. He found that the incidence of the plerocercoids of *Triaenophorus stizostedionis* was 64 percent in 1950 and 48 percent in 1951. Miller (1948) reported the incidence of the plerocercoids of *Triaenophorus crassus* in the tullibee and whitefish of Lesser Slave Lake, Canada to be quite variable over a period of years. From 1944 to 1947 the incidence of this cestode in the tullibee varied from 93 to 11 percent, while in the whitefish it varied from 31 to 7 percent.

Lastly, a species of fish has been collected for several successive months and the incidence of a particular parasite determined for each month. Haley (1954a, 1954b) collected the smelt *Osmerus mordax* in this manner, from Lake Winnisquam, New Hampshire, during February, April and May, 1952 and determined the incidence of the microsporidian *Glugea hertwigi* to be 0, 6, and 17 percent for the indicated months. This and his work on the smelt of the Great Bay Region, New Hampshire, strongly suggests a seasonal variation in the incidence of diseases or parasites common to fishes.

Lymphocystis is an infectious disease caused by an intracellular virus. The disease causes an enlargement of the host's connective tissue cells and manifests itself in the form of large grayish granular tumors on the fins and body of both fresh and salt water fishes. A typical case of lymphocystis in the white crappie can be seen in Figure 1. Lymphocystis is of widespread occurrence in temperate North America (Nigrelli, 1954) and

FIGURE 1.—A white crappie, 6.5 inches long, infected with lymphocystis and showing the typical location of the tumor. Insert is an enlarged view of the right side of the caudal fin.

the members of the Centrarchidae of this region seem to be more readily susceptible to it than other fishes, although the walleye also is quite susceptible (Weissenberg, 1945). For a summary of the literature dealing especially with the cytological aspects of the disease, see Nigrelli, 1954.

Lymphocystis has been reported to occur in the white crappie of Illinois by Hansen (1951). He found that 1.4 percent of the white crappie were infected from Senachwine Lake, 9.5 percent from Lake De Pue, and 19.5 percent of those from Lake Chautauqua.

Borges (1950) examined 299 white crappie from the same body of water where the present study was made and found that 10.7 percent of the fish were diseased. He stated that "many were infested with fungus infection on the caudal, dorsal and anal fins." I believe that the growths he saw on the fins of the white crappie were actually the tumors caused by the lymphocystis virus. At no time during this present study was a fungus noticed on the fins of the white crappie.

Materials

The white crappie used in this study were captured in the Niangua Arm of the Lake of the Ozarks, a Central Missouri impoundment. Fish were collected monthly from June, 1950 through June, 1951. They were collected for an age and growth study and were processed in the usual manner. In addition the 5,906 fish were examined for external parasites and lymphocystis; when the tumors were present, their location was noted. (In some instances only the presence of the tumors was recorded). Gross internal examination of the body cavity was also made. An additional 1,593 white crappie were captured during the month of October for the years 1952 through 1955 and were similarly examined.

Seasonal Variations in the Incidence of Lymphocystis

There are conflicting reports in the literature as to the time of the year when lymphocystis reaches a maximum. Nigrelli (1954) stated that the disease appears in the spring, reaches a maximum in the summer, and then gradually disappears in the fall and winter, although he does not document this. In the New York Aquarium, it was high in the summer and low in the winter (Nigrelli and Smith, 1939).

In opposition, Weissenberg (1945) reported that the disease reached epidemic proportions in the Philadelphia Aquarium during the winters of 1938–1939 and 1939–1940. He also cited an epidemic at the Dexter, New Mexico fish hatchery during the winter of 1940–1941.

Hansen (1951) reported a low incidence for the disease in the spring of 1942 for two lakes in Illinois and then an extremely high incidence in the fall of 1943 for another lake in Illinois. Borges' original data, which are on file at the Missouri Wildlife Research Unit and which have been re-examined, show that the major portion of infected fish were captured in August 1947. This indicates that at the Niangua Arm of the Lake of the

Ozarks in 1947 the disease reached maximum proportions during the summer.

Figure 2 presents the percentage of white crappie which were infected with lymphocystis during each month of this study. It is apparent that the percentage of fish infected with lymphocystis increased in the spring and reached a maximum in July. There was a gradual decrease in August and then a rapid decrease to a low in the month of October. In November, the disease became prevalent again and then gradually declined during the winter months until April of the following spring, at which time it reached a minimum. After April, it gradually increased again to the same magnitude in June 1951 as it was in June 1950.

The question arises as to whether the low in October 1950 is real or

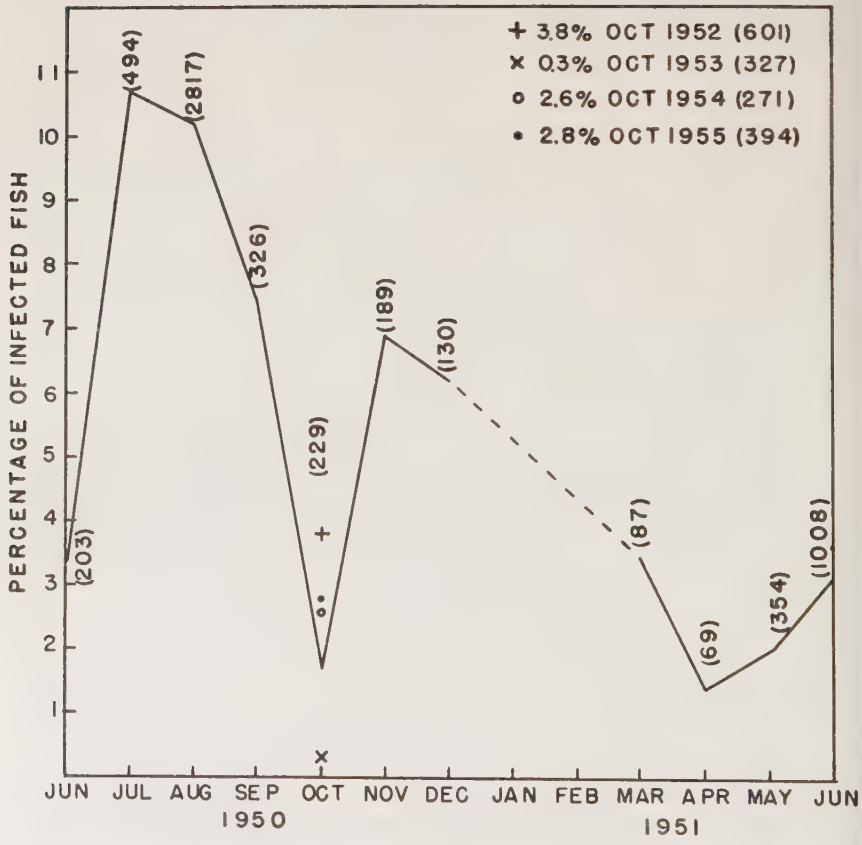

FIGURE 2.—Percentages of white crappie infected with lymphocystis for the months June 1950 through June 1951. Numbers in parentheses represent the monthly sample size. Symbols represent the percentages of infected fish for the month of October 1952–1955.

apparent especially when the percentage for this month is compared with the percentages for the following November and December. I believe that this is real and not due to sampling errors. Nigrelli (1954) stated that lymphocystis tumors may appear or disappear within a few days and it is reasonable to assume that some environmental factor or factors caused a reappearance of the disease during the month of November. Turnover occurs toward the end of October and it is possible that an increase of the disease in November is associated with a decrease in the water temperature. Also, the incidence of the disease during the month of October for the years 1952 through 1955 was of similar magnitude as in October 1950.

The variation in the incidence of the disease during the month of October for the 5 years is probably a reflection of the incidence of the disease during the preceding summers. That is, it is probable that a larger portion of the population of white crappie were infected in the summer of 1952, when the incidence for that October was high, than during the summer of 1953, when the incidence for October was low.

Location of the Tumors

Weissenberg (1945) has compared the appearance of lymphocystis infections in the centrarchids with that of the walleye and stated that in the centrarchids lymphocystis is restricted to the fin borders and seldom occurs on the body.

Table 1 shows the location of the lymphocystis tumors as they were found on the white crappie during each of the collecting periods. It is ap-

Table 1.—*The location of lymphocystis tumors on white crappie*
[Expressed as number and percentage of the infected fish]

Location of tumors	June 1950—June 1951		October 1952—1955	
	Number	Percentage	Number	Percentage
Caudal fin	170	68	26	62
Pectoral fin	24	10	6	14
Dorsal fin	16	6	2	5
Anal fin	3	1	1	2
Pelvic fin	1	[1]0	1	2
Body	2	1	1	2
Multiple infection[2]	35	14	5	12
Number infected	251	100	42	100

[1]Less than 0.05
[2]Multiple infection means that two or more fins of the same fish were infected

parent that the fins contained a greater percentage of tumors than did the body; thus Weissenberg's findings are corroborated. The caudal fin was infected more than any of the other fins. The incidence of tumors on the caudal fin (68 and 62 percent of all the infected fish examined) would have been considerably higher if the caudal infections which were included

under multiple infection had been considered by themselves. It is probable that the caudal fin showed the greater percentage of tumors because it is more subjected to injury and comes into contact more readily with infected fish, especially in young white crappie which characteristically school.

Of the white crappie examined, only one percent evidenced lymphocystis tumors on the body. No lymphocystis tumors were found in the body cavity of a large number of the white crappie examined internally.

Size of Infected White Crappie

Lymphocysts as it occurs in the white crappie is mostly limited to fish less than 170 millimeters in total length (6.7 inches), as was also found by Borges (1950).

A length frequency distribution was made of the 7,499 white crappie and the number of infected fish in each class interval was noted (Table 2). Of the infected fish collected in 1950–1951, 97 percent were less than 170 millimeters in total length, while only 3 percent of the infected fish were between 170 and 369 millimeters. In 1952, 48 percent of the infected fish were less than 170 millimeters in total length, while 52 percent were longer. In the remaining years, 1954 and 1955, approximately 85 percent of the infected fish were less than 170 millimeters long. The exception was in 1953 since only one individual was diseased.

The data for the years 1950–1951 and 1952, were statistically examined for first and second order interaction by the method of chi-square. The test for interaction between infection and size of fish was highly significant ($P<.01$) in 1950–1951 but not significant ($P>.05$) in 1952; possibly because of the influence of the 1949 year class.

The second analysis, a test for second order interaction between infection, size of fish and years, is also significant ($P<.02>.01$). This means that not all the difference in rate of infection can be explained either by change in year or by difference because of size of fish.

This may be interpreted to mean that the 1949 year class, which made up most of the small fish in 1950–1951 and made up most of the large fish in 1952, carried the infection more than other fish.

The smaller fish, less than 170 millimeters in total length, showed a larger incidence of the disease probably because they were more numerous than the larger fish and had a greater tendency to school, which would expedite the spread of the disease. Also, it is probable that many of the larger fish may have been infected when they were small, recovered from the disease, and subsequently developed an immunity to further infection by the lymphocystis virus (Nigrelli, 1954).

Table 2 shows that the abundant 1949 year class carried the disease over a period of several years. The average total length for this year class for each month is represented by the boldface type in the table. In 1950, almost all of the infected fish were less than 170 millimeters long and were represented by the 1949 year class. In 1951, the average length of this year class exceeded 170 millimeters in June and its members still carried the

TABLE 2.—*Length frequency distribution of white crappie showing the total number and number of infected fish (in parentheses) by months*

[Figures in bold face include the mean lengths of the 1949 year class]

Total length millimeters	1950							1951				1952	1953	1954	1955
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mar.	Apr.	May	June	Oct.	Oct.	Oct.	Oct.
60-69	.. ..	... ..	....	... ...	.. ..	.. ..	.. ..	.. ..	... ..	... ..	... ..	... ..	.. ..	.. ..	1 ..
70-79	1 ..	... ..	....	... ..	.. ..	1 ..	.. ..	.. ..	.. ..	... ..	... ..	... ..	1 ..	.. ..	5 ..
80-89	1 ..	... ..	1	... ..	.. ..	1 ..	.. ..	.. ..	... ..	3 ..	1 ..	3 (1)	4 ..	.. ..	16 (2)
90-99	7 (1)	... ..	....	... ..	.. ..	1 ..	2 (2)	1 ..	... ..	10 ..	1 ..	9 (2)	4 ..	.. ..	25 ..
100-109	13 ..	1 ..	....	1 ..	.. ..	.. ..	.. ..	1 ..	... ..	11 ..	7 ..	8 (1)	9 ..	.. ..	22 ..
110-119	**35 (5)**	3 (1)	2 ...	2 ..	.. ..	2 (1)	.. ..	2 ..	.. ..	12 (1)	51 (4)	8 (1)	18 ..	2 ..	12 ..
120-129	20 (1)	59 (14)	6 (2)	... ..	.. ..	.. ..	1 ..	.. ..	.. ..	1 (1)	139 (7)	... ..	13 ..	.. ..	4 ..
130-139	2 ..	**126 (24)**	52 (7)	16 (1)	.. ..	4 ..	1 (1)	2 ..	2 (1)	... ..	61 (8)	1 ..	.. ..	2 ..	2 ..
140-149	3 ..	102 (8)	962 (142)	50 (4)	18 (1)	11 (2)	16 (1)	15 ..	3 ..	27 ..	91 (1)	14 (3)	2 ..	9 (1)	21 ..
150-159	22 ..	33 (3)	**1245 (116)**	**125 (13)**	88 (3)	**94 (5)**	60 (2)	**32 (3)**	**29** ..	**142 (2)**	170 (3)	94 (1)	7 ..	61 (3)	124 (3)
160-169	46 ..	17 (1)	140 (17)	68 (5)	**47** ..	56 (4)	**34 (2)**	8 ..	20 ..	80 (1)	229 (3)	51 (2)	24 ..	91 (2)	88 (4)
170-179	21 ..	45 (1)	41 (1)	16 (1)	8 ..	7 (1)	3 ..	4 ..	2 ..	12 (1)	**109 (2)**	14 ..	23 ..	37 (1)	32 (2)
180-189	6 ..	58 ..	54 ...	3 ..	8 ..	2 ..	3 ..	5 ..	.. ..	4 ..	69 (2)	28 (3)	13 ..	14 ..	10 ..
190-199	3 ..	33 ..	96 ...	6 ..	5 ..	1 ..	1 ..	3 ..	1 ..	4 ..	27 (1)	44 (1)	12 ..	4 ..	7 ..
200-209	1 ..	6 (1)	129 (3)	7 ..	8 ..	4 ..	1 ..	5 ..	.. ..	3 ..	3 ..	115 (5)	23 (1)	2 ..	2 ..
210-219	2 ..	1 ..	54 ...	9 ..	4 ..	3 ..	2 ..	1 ..	1 ..	5 ..	7 ..	**98 (2)**	30 ..	3 ..	3 ..
220-229	2 ..	1 ..	18 ...	11 ..	7 ..	.. ..	1 ..	1 ..	.. ..	6 ..	7 ..	66 (1)	16 ..	2 ..	1 ..
> 230	18 ..	9 ..	17 ...	12 ..	36 ..	2 ..	5 ..	7 ..	11 ..	34 ..	36 ..	48 ..	129 ..	44 ..	19 ..

tumors of lymphocystis. Finally in 1952 when the members of this year class were 3 years old, their average length was approximately 215 millimeters and they still evidenced the disease.

This indicates that some fish may be infected by lymphocystis for at least 3 years and may not develop an immunity to the disease as postulated above; or that the disease may be active among the members of an abundant year class for at least 3 years.

Effect of Lymphocystis on White Crappie

The ultimate effect of lymphocystis on the well being of the white crappie remains unknown. Apparently the disease is seldom fatal (Nigrelli and Smith, 1939, and Watson, 1954) and infected fish will recover. At no time during this study were dead white crappie noticed nor was there an apparent decrease in the vitality of infected fish.

Weissenberg (1945) reported that infected bluegills and pumpkinseed heal after the tumors have sloughed off of the fins. There was evidence that this occurred in the white crappie, because some captured fish had large areas of the caudal fin missing just as though a tumor had been excised from the fin.

The white crappie infected with lymphocystis apparently did suffer some ill effects from the disease because infected fish weighed 3 to 5 percent less than uninfected fish of the same length. Watson (1954) reported that infected walleyes weighed 5.5 to 6.5 percent less than sound walleyes of the same length.

The disease has little economic or esthetic significance in the white crappie. In the case of a commercial species such as the walleye, the disease can become economically significant. It can be esthetically significant also because fishermen reject fish that are heavily infected with lymphocystis tumors. This is not the case in the white crappie since most of the infected fish are less than 6.7 inches long and do not interest the fisherman because of the small size.

Other Fishes Infected by Lymphocystis

Although thousands of other fishes have been captured at the Niangua Arm of the Lake of the Ozarks, during the past 5 years, only one other species was found to be infected with lymphocystis. This was a walleye which had a small lymphocystis tumor on its body. Although other centrarchids are abundant in the Niangua Arm, none were ever found with lymphocystis tumors. This supports the idea of Weissenberg's (1945) that virus strains may be adapted to their hosts and generally will not infect other species of fish, even though interspecific and interordinal transmissions have been accomplished in the laboratory.

Acknowledgments

I am indebted to Bertram Litt and the late Richard Marzolf for their aid in collecting fish during 1950 and 1951. During the subsequent years, many students a

the Missouri Wildlife Research Unit helped in the field work and to them I express my gratitude. Dr. Peter W. Frank aided with the statistical analysis.

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Part 2
Business Sessions

THE AMERICAN FISHERIES SOCIETY

Eighty-Fifth Annual Meeting

The eighty-fifth annual meeting of the Society was opened in the Bon Air Hotel, Augusta, Georgia, Wednesday, September 14, 1955. The agenda were as follows:

Wednesday, September 14

Morning and Afternoon: Joint field trip with the International Association of Game, Fish and Conservation Commissioners to the Clark Hill Reservoir.

Evening: Annual joint banquet—Crystal and Plantation Rooms, Bon Air Hotel.

Thursday, September 15

Morning: Opening remarks of the President; appointment of sessional committees; reports of officers, chairmen of regional divisions special committees, and standing committees.

Afternoon: Presentation and discussion of papers on international relations, national-state relations, hydrobiology and fish culture, and commercial fisheries.

Friday, September 16

Morning: Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees; election of officers and installation of the new President; concluding business.

REGISTERED MEMBERS IN ATTENDANCE

Aldrich, A. D., Fla.
Allison, Leonard N., Mich.
Anderson, William W., Ga.
Archer, H. W., Mo.
Armbruster, Daniel C., Ohio

Bailliere, Lawrence, Mo.
Bardach, John E., Mich.
Barnickol, Paul G., Mo.
Baxter, William, Del.
Billy, George, Ohio
Bode, I. T., Mo.
Borglin, J. N., Del.
Bryant, Maurice, Ga.
Burner, Charles C., Kan.
Butler, George Edward, Man.
Buck, D. Homer, Okla.
Burdick, George E., N.Y.
Byrd, I. B., Ala.

Carbine, William F., D.C.
Christensen, Kenneth E., Mich.
Clark, Minor E., Ky.
Clay, William M., Ky.
Clemens, Howard P., Okla.
Cobb, Roland H., Maine
Cornell, James H., N.C.
Cottam, Clarence, Texas
Crowe, Walter R., Mich.
Cummins, Robert Jr., Ohio

Davis, James T., La.
Day, Albert M., D.C.
Dequine, John F., Fla.
Dickson, Arthur W., N.C.
Dickson, Fred J., Ga.
Donaldson, Lauren R., Wash.
D'Sinter, Herbert F., Ill.
Dumont, William H., D.C.

Eipper, Alfred W., N.Y.
Erickson, James G., Ohio
Eschmeyer, Paul H., Mich.

Farley, John L., Va.
Fearnow, Theodore C., Pa.
Fetterolf, Carlos M., Jr., Tenn.
Fielding, James Russell Jr., Ga.
Fleener, George G., Mo.
Forney, John L., N.Y.
Franz, Robert K., Ga.
Freeman, Berry O., Miss.
Fukano, Kiyoshi G., Mich.

Fuller, J. C., S.C.

Gatlin, John C., N.M.
Gascoyne, Rod, Mass.
Geagan, Donald W., La.
Gentry, Glen, Tenn.
Gordon, Seth, Calif.
Gottschalk, John S., Va.
Gunter, Gordon, Miss.

Hall, Gordon E., Fla.
Hall, John F., Ky.
Harkness, William J. K., Ont.
Harry, George V., Mo.
Hassler, William W., N.C.
Hayford, Charles O., N.J.
Hazzard, Albert S., Mich.
Heinen, Edward T., Fla.
Hemphill, Jack E., Ariz.
Hester, John M., Ala.
Hile, Ralph, Mich.
Hooper, Frank F., Mich.
Hudson, Stanton, Mo.
Hueske, Edward E., Va.

Jackson, Samuel W. Jr., Okla.
Janzen, Daniel H., Minn.
Jenkins, James H., Ga.
Jenkins, Robert M., Okla.
Joslin, Verne E., Minn.

Kelly, H. D., Ala.
King, John, Okla.
King, Willis, Ga.

Langlois, T. H., Ohio
Larimore, R. Weldon, Ill.
Lawrence, John M., Ala.
Lawrence, William M., N.Y.
Laythe, Leo L., Ore.
Leedy, Daniel L., D.C.
Lennon, Robert E., W. Va.
Luethy, Don R., Fla.

Macioleck, John A., Calif.
MacKay, H. H., Ont.
Mair, W. Winston, Ont.
Maxwell, John M., Mass.
May, Otho D. Jr., Ga.
McBroom, James T., D.C.
McCoy, H. W., Okla.
McKernan, Donald L., Alaska
Meehean, O. Lloyd, D.C.

Miller, Frank, Wis.
Miller, Lawrence F., Ala.
Miller, Richard B., Alta.
Millest, R. H., Ont.
Moffett, James W., Mich.
Moore, George C., La.
Moyle, John B., Minn.
Murphey, John B., Tenn.

Odum, Howard T., N.C.
Olson, Philip A., Wash.

Padfield, James H. Jr., Ga.
Parr, Sam, Ill.
Parsons, John W., Ga.
Pautzke, Clarence F., Wash.
Phillips, Arthur M. J., N.Y.
Pillow, Braden, N.C.
Prather, E. E., Ala.
Pratt, Virgil S., Idaho
Pritchard, A. L., Ont.

Raney, Edward C., N.Y.
Reid, Cecil W., Texas
Richardson, Frank, N.C.
Riggs, Carl D., Okla.
Roach, Lee S., Ohio
Rutherford, Robert M., D.C.

Schafer, Harry E. Jr., La.
Schneberger, Edward, Wis.
Scott, Donald C., Ga.
Seaman, Elwood A., Pa.
Shapovalov, Leo, Calif.
Shoemaker, Carl D., D.C.
Smith, Marvin, Ga.
Smith, Spencer H., Miss.
Smith, William A. Jr., Ky.
Snieszko, Stanislas F., W. Va.
Speaker, E. B., Iowa
Sprecher, G. E., Wis.
Soumela, Arnie J., D.C.
Springer, Stewart, Va.
Stephens, Robert F., N.C.
Stevens, Robert E., N.C.
Stroud, Richard H., D.C.
Sullivan, Martin W. Sr., N.C.
Summers, Max W., La.
Suttkus, Royal D., La.
Swift, Ernest, D.C.
Swift, Lloyd W., D.C.
Swingle, H. S., Ala.

Tatum, Buford, N.C.
Taube, Clarence M., Mich.
Tebo, Lee B. Jr., N.C.
Thompson, Fred A., N.M.
Thompson, William H., Okla.
Thorpe, Lyle M., Conn.
Toole, Marion, Texas
Tunison, A. V., D.C.
Turner, William L., Tenn.

Viosca, Percy Jr., La.
Voigt, L. P., Wis.
Voigt, William Jr., Pa.

Wade, Gerry, Maine
Webb, Robert T., Ga.
Whiteleather, Richard T., D.C.
Wilkins, L. P., Tenn.
Williams, John E., Mich.
Wolf, Kenneth E., W. Va.
Wood, Roy K., Ga.
Wright, Stillman, D.C.

Yashouv, Abraham, Israel

Zeller, Howard D., Ga.

OPENING REMARKS OF THE PRESIDENT

A. L. Pritchard

In the few minutes at my disposal it is my duty to report to you on the status of the Society. I think that your Society is in a healthy condition. The membership is at a high level, the finances are sound, and our interest in fisheries affairs is broad and intense.

In a society such as ours the outside shell may be hard, but the feelings of individual members may be rather turbulent. Through the year we have had a lot of criticism and discussion. That I consider extremely healthy. If it had not occurred, I would have reported to you today that there was something wrong with the Society.

Another indication that the Society is sound, is that busy individuals appointed to committees accepted, fell to work with a will, and did their very best for the Society. I cannot mention them all individually, but I would like to single out the Secretary-Treasurer for special praise. He has been conscientious, he has been interested, and he has really carried the organization.

Now, it is with some hesitancy that I endeavor to deliver what you may accept, if you like, as a farewell message. I would not do so if I did not feel that my unique personal experience in the field of fisheries indicated that I should. As a scientist (and I trust that my friends will not object to that too forcefully for a minute) over a period of 25 years, I should like to warn fisheries workers that times have changed.

Most of us will remember how easy it was, in the early 20's, to make a reputation in our field. It was not necessary to show signs of genius because almost everything we touched was new. As a result we built up a group of research workers who were busy making observations and collecting information.

Shortly thereafter we came to realize that if some of the material which we collected was not applied due to our peculiar economic organization or situation, we might fall short of funds for further research. Therefore, an attempt was made at application, and whether it was good or bad, from our point of view, the early efforts were eminently successful. I think, for instance, of such things as the Fur Seal Convention. Many of you think that there was very little scientific information involved, but the very basis of that convention was scientific. I think of the International Fisheries (Halibut) Treaty which we in Canada rate very highly since it was the first treaty signed by Canada as an independent Dominion. I think of the progress which was made in salmon research. But I want to ask if these successes did not perhaps lead to some slight dishonesty on the part of the scientists.

That is why I say that we are now in a critical period. Some scientists

still feel that they have to convince the populace (as opposed to the administrators) that they have a useful purpose in life. Actually, they do not have to do that. Scientists have been accepted; but their serious responsibility is now to avoid having too many failures. When failures outnumber successes, there can be only one result for fisheries science.

I appeal to you scientists and fisheries management officers to think this situation over and to be honest. If, in your researches, you reach a conclusion which you think is supportable and sound, say so, and fight for that conclusion. But if you have only come to the place where you can make an informed guess, say that, too. Be sure to outline clearly the basis of your conclusions and try to indicate the chances of success. You will notice that I say, be sure and fight. That is right. Fight for your case, but don't over-fight.

The second thing I would ask you to do is to remember that you are scientists and fisheries workers and that in this great field of management you have a particular job to do. You are not expected to do everybody else's job: just be a scientist, do your job well, see that your results get to the place where they are supposed to go, and don't try to take over other people's jobs.

You will find, in your organization, certain ogres called administrators. As an administrator, might I tell you that the two jobs of scientist and administrator definitely are not interchangeable. It doesn't necessarily mean that a scientist could not be an administrator, but it does mean that not every scientist can be an administrator, and it also means that not every administrator can be a scientist.

Science is science; logical, hard, and full of facts. Administration, by contrast, is an art, and the administrator is just like a painter. He has to blend and use the various colors, in this case colors represented by the hard, basic facts—scientific, economic, and political. And "politics" as I use the word, does not necessarily refer to any given party system. Politics to my mind means a study of the influence of any particular decision on the people, the body politic.

The administrator, as I say, must blend all these ingredients and eventually come up with a picture which is not only perfect but which will, in his opinion, best suit and most benefit the people in the area for which he is responsible. He must make the decisions. And you who are in research can help him most by making sure that you give him the information he is supposed to have, and that you are honest about it.

On the other hand, we who are administrators carry an extremely heavy burden. We must recognize, without any false modesty, that we are neither omniscient nor omnipotent. It is an obvious fact that no administrator can get along without the component parts of his organization. Therefore, efficient and complete collaboration is essential. We administrators must recognize that the scientific fishery worker is not just a fashion which we have to accept because he happens to be popular. We must recognize and

perhaps admit at times, although not too often, that we ourselves are completely dependent upon him.

I feel that at the present time the fisheries, in this respect, are in a critical period. There are no halfway measures. We must do some cogitating and, eventually, fit ourselves into an organization in which there is absolute and complete collaboration, and respect of the one component for the other. I think, and I say this with some hesitation, that we must closely analyze our actions and be sure that personal advancement is kept secondary to the good of the cause. It is hard to ask anyone not to think of personal advancement, but I believe you will agree that the prime requisites for all of us in fisheries are honesty and cooperation, so that we in this decade and in the decade to come cannot be accused of ruining, through lack of cooperation, a science which has been built up by the hard work of our eminent predecessors.

I leave that thought with you and I plead for mutual consideration and understanding.

APPOINTMENT OF SESSIONAL COMMITTEES

Nominating

Albert S. Hazzard, Michigan, *Chairman*
George E. Butler, Manitoba
James H. Cornell, North Carolina
Seth Gordon, California
William J. K. Harkness, Ontario

Resolutions

H. H. MacKay, Ontario, *Chairman*
Paul G. Barnickol, Missouri
Lauren R. Donaldson, Washington
John S. Gottschalk, Virginia
A. V. Tunison, District of Columbia

Auditing

Edward Schneberger, Wisconsin, *Chairman*
William J. K. Harkness, Ontario
O. Lloyd Meehean, District of Columbia

Time and Place

Fred A. Thompson, New Mexico, *Chairman*
William M. Lawrence, New York
Gerry Wade, Maine
Richard A. Wagner, Washington

Publicity

James H. Cornell, North Carolina, *Chairman*
Fred J. Dickson, Georgia
Donald C. Scott, Georgia

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

EVERETT B. SPEAKER

It is always a pleasure for the Secretary-Treasurer to report the financial status of an organization if it is in good order. I am pleased to report that the American Fisheries Society is in excellent financial condition at this time.

The greatest item of expense, of course, is the publication of the TRANSACTIONS. Our publishers have done an excellent job and the TRANSACTIONS reflect the high quality of superb craftsmanship. We are justly proud of this publication and feel it is our responsibility to keep it on the highest possible plane in accordance with the traditions of the Society. Mr. Kiyoshi G. Fukano, Chairman of the Editorial Board, advises us we can expect Volume 84 of the TRANSACTIONS to appear in the near future.

The Membership Committee, under the able leadership of our distinguished Vice-Presidents George E. Sprecher and Clarence F. Pautzke, gave an excellent account of their endeavors. The untiring efforts of the Canadians and members throughout the various regions of the United States brought the present membership to its highest point in our history. Many individuals and libraries throughout the world joined our ranks.

At the close of the Seattle meeting we had 1,581 members, and on August 31, 1955, there was a total of 1,743 not counting the 32 applications received at this meeting.

On September 1, however, 122 members were dropped for nonpayment of dues, death, and other reasons, bringing our present membership to 1,653. Thanks are extended to all who participated in the membership drive.

All three of the Divisions of the Society have been actively engaged in fisheries work during the past year, and reports from their officers indicate their annual meetings have been highly successful. Consideration is being given at this time to the possible organization of a North Central Division of the Society.

The response from the Executive Committee was heartening, and it was largely through their efforts we were able to bring you items of interest concerning Division activities and important fishery events through the media of our Newsletter.

Librarian Howard A. Tanner gave an excellent account of sales of TRANSACTIONS and the new Cumulative Index.

Perhaps no one has worked more diligently to promote a magnificent program for our annual meetings than Fred Dickson and his Program Committee, and the results of their laborious efforts are reflected in the quality of this conference.

The financial report follows.

REPORT OF RECEIPTS AND DISBURSEMENTS

July 1, 1954, to June 30, 1955

GENERAL FUND

Balance on hand, July 1			$ 5,186.93
Receipts			
Annual Dues			
Individual memberships			
for the years 1951–52	$ 4.50		
1952–53	108.00		
1953–54	432.50		
1954–55	5,150.50		
1955–56	218.00		
1956–57	.50	$ 5,914.00	
State memberships			
for the years 1953–54	$ 80.00		
1954–55	1,400.00		
1955–56	40.00	$ 1,520.00	
Library memberships			
for the years 1953–54	$ 20.00		
1954–55	387.00		
1955–56	41.00	$ 448.00	
Club memberships			
for the years 1954–55	$ 250.00		
1955–56	10.00	$ 260.00	
Sale of Transactions and Special Publications			$ 1,265.25
Sale of Index			16.50
Refund on Insurance			17.82
Registration fees at Seattle Meeting			340.00
Reimbursement for postage for reprints			4.06
Total Receipts			$ 9,785.63
Balance, July 1, Plus Total Receipts			$14,972.56
Disbursements			
Printing of TRANSACTIONS	$ 6,048.46		
Printing of Index	2,000.62		
Other printing	741.22		
Reprints—Craft Press	40.54		
Indexing Transactions	100.00		
Postage and supplies	394.22		
Travel Expense for Officers of the Society	392.49		
Insurance	178.69		
Fidelity Bond	18.75		
Clerical Services	226.35		
Dues to Natural Resources Council	50.00		
Petty cash fund for Editor	54.00		
Assistance, Seattle Meeting	400.00		
Miscellaneous	4.50		
Less: Total Disbursements			$10,649.84
Gross Balance, General Fund, June 30, 1955			$ 4,322.72
Less: Bank debit memos, etc.			10.00
Net Balance, General Fund, June 30, 1955			$ 4,312.72

PERMANENT FUND

Balance on Hand, July 1, 1954		$ 365.52
Receipts		
Patron Membership	$ 250.00	
Individual Life Memberships	150.00	
Dividend Income		
Consumers Power Co.	61.60	
Central Illinois Light Co.	13.20	
Total Receipts		474.80
Balance July 1 Plus Total Receipts		$ 840.32
Disbursements		
None		
Net Balance, Permanent Fund, June 30, 1955		$ 840.32

RECAPITULATION

Net Balance, General Fund, June 30	$ 4,312.72
Net Balance, Permanent Fund, June 30	840.32
Net Balance, Both Funds, June 30, 1955	$ 5,153.04

SECURITIES HELD JUNE 30, 1955

(1) U. S. Government Savings Bonds

Number	*Date Purchased*	*Mature Value*	*Current Value*
D682395F	8/29/49	$ 500.00	$404.50
M1610061F	8/29/49	1,000.00	809.00
D702345F	12/15/50	$ 500.00	393.00
M1703542F	12/15/50	1,000.00	786.00
M1773328F	10/31/51	1,000.00	767.00
M1773329F	10/31/51	1,000.00	767.00
M1773330F	10/31/51	1,000.00	767.00
M18441J	9/26/52	1,000.00	750.00
M18346J	9/26/52	1,000.00	750.00
M18347J	9/26/52	1,000.00	750.00
M18348J	9/26/52	1,000.00	750.00
M18349J	9/26/52	1,000.00	750.00
M18350J	9/26/52	1,000.00	750.00
M18351J	9/26/52	1,000.00	750.00
M18352J	9/26/52	1,000.00	750.00
		$14,000.00	$10,693.50

(2) Consumers Power Company No. G-6085, 28 shares at 47 3/8	$ 1,326.50
(3) Central Illinois Light Company No. B-1752, 6 shares at 52 1/2	$ 315.00
Total	$12,335.00

PROPOSED BUDGET FOR 1955–1956

GENERAL FUND

Balance on hand July 1, 1955		$ 4,312.72
Estimated Receipts:		
Annual dues	$ 8,200.00	
Sale of publications	1,200.00	
Total estimated receipts		$ 9,400.00
Net estimated income		$13,712.72
Estimated Disbursements:		
Printing of Transactions—Vol. 84	$ 6,200.00	
Other printing	750.00	
Clerical services	200.00	
Postage and supplies	400.00	
Editing	175.00	
Reporting services	300.00	
Insurance	180.00	
Fidelity Bond	20.00	
Travel expense	200.00	
Dues—Natural Resources Council	50.00	
Miscellaneous	250.00	
Total estimated disbursements		$ 8,725.00
Net Estimated General Fund Balance, June 30, 1956		$ 4,987.72

PERMANENT FUND

Balance on hand July 1, 1955	$ 840.32	
Value of securities held July 1, 1955	12,335.00	
Estimated Receipts:		
Dividends	$ 75.00	
Increment on U. S. Government Bonds	215.00	
Net Estimated Permanent Fund Balance, June 30, 1956		$13,465.32
Net Estimated Balance, Both Funds, June 30, 1956		$18,453.04

REPORT OF THE LIBRARIAN

HOWARD A. TANNER

During the period from September 1, 1954 to September 1, 1955, the Office of the Librarian has sold a total of 394 Volumes for $1,347.00, 58 Special Publications worth $14.50, fourteen 1872–1929 Indexes, both paper and cloth bound, worth $16.50, and nine 1929–1952 Cumulative Indexes worth $9.00. The total sales value of these materials is $1,387.00, of which $1,097.75 has been forwarded to the Secretary-Treasurer. Accounts outstanding total $289.25.

Several back volumes of the TRANSACTIONS were purchased recently for a total cost of $67.75. The overrun of Volume 83 was received from the printers in December.

In my report to the Society at last year's meetings in Seattle, I made it clear that because of inadequate secretarial help I found it necessary to request that a new librarian be elected. Since that time the Librarian of Colorado A & M College has generously offered to take over the duties of Librarian of the American Fisheries Society. There are several advantages to the Society with this arrangement. We are in effect being offered free secretarial help necessary to the functions of the Office of the Librarian, and if we desire it, a more or less permanent fireproof home for our two or three tons of back volumes. If the Membership approves this arrangement an expensive move of the library material will be avoided.

Under the arrangement as suggested by Dr. Hazzard, Chairman of the Nominating Committee, I will remain as Official Librarian. The books will be subject to my audit and inventory, and I will answer any inquiries of a technical nature. The complete bound set of TRANSACTIONS entrusted to the Librarian will remain in my office.

If these arrangements are accepted by the Membership I would like to suggest that the Society recognize the generous nature of this offer from the Colorado A & M College Library in some appropriate manner.

REPORT OF CHAIRMAN OF THE NORTHEASTERN DIVISION

JOHN R. GREELEY

The third annual meeting of the Northeastern Division, took place at Atlantic City, New Jersey, March 23, 24 and 25, 1955. It was held jointly with the Northeast Section of the Wildlife Society, the Northeast Section of the Conservation Law Enforcement Chiefs, the Northeast Section Fish, Game and Conservation Commissioners and the Game Breeders Association of New Jersey. Attendance was high there being approximately 120 persons registered at fisheries sessions, representing 13 states and 3 provinces.

In view of the National Wildlife Conference having been held in Montreal only a few days previously many persons were unable to be present. At the business meeting it was recognized that a date which would not be so close as to conflict with American Fisheries (September) or Wildlife Conference (March) should be set. A date of late January, at Pittsburgh, Pa., was proposed for a similar northeastern joint conference and was approved by the Division. However, subsequent work on arrangements indicated a midwinter date at Pittsburgh to be impossible to arrange and the 1956 meeting was set for May 14, 15 and 16 at Hotel William Penn, Pittsburgh. Officers for the 1956 meeting are: Chairman John R. Greeley, New York, Vice-Chairman H. Wesley Curran, Ontario, and Secretary Harry D. Van Meter.

The Atlantic City program included Division sessions on Warm Water Fisheries Management, Trout and Salmon Management, Marine Fisheries

and Fish Culture. There were two joint sessions covering many subjects of interest, including matters of regional, federal and state coordination. The increased attendance by persons interested in marine fisheries problems was worthy of note. Mimeographed transactions of the conference were supplied, a registration fee of $1.00 being voted to help defray such incidental expenses. Subsequent to the Atlantic City meeting a Program Committee, Chairman Gordon L. Trembley, Pennsylvania and a Publicity Committee, Chairman C. A. Tryon, Jr., Pennsylvania, were appointed.

REPORT OF CHAIRMAN OF THE SOUTHERN DIVISION

C. J. Chance

The Southern Division of the American Fisheries Society opened its third annual meeting on November 1, 1954, in New Orleans. This meeting, along with the annual meeting of the Southeastern Section of the Wildlife Society and the Southeastern organization of Game and Fish Law Enforcement Officers, was held at the invitation of and concurrently with the eighth annual conference of the Southeastern Association of Game and Fish Commissioners.

The threadfin shad, white bass, inland commercial fisheries, rough fish control, weed control, creel census, effect of siltation on trout streams, and farm pond management represented the bulk of the subject material for papers and panel discussions. In addition, two papers on the striped bass, *Roccus saxatilis,* and one paper on fish diseases were of considerable general interest and greatly diversified the progrm.

Members in attendance numbered 76 and nonmembers 11. All Southern Division states and Pennsylvania, New York, and Washington, D.C. were represented. According to the membership list of May 1955, the Southern Division members totalled 234. This figure represents a loss of 5 members siince November, 1954

The Southern Division is financially solvent and has been able to meet the small fiscal obligations necessary for its operation.

Mr. Don R. Leuthy, program chairman for the fourth annual meeting, has reported considerable difficulty in obtaining papers for the early October, 1955, meeting at Daytona Beach. Presumably, this results from the time proximity of the Augusta and the Daytona meetings. While this is an unfortunate coincidence and one which the Southern Division had no opportuninty to avoid, Mr. Leuthy is making every effort to assemble an interesting program for October 3, 4, and 5, 1955. Officers for the 1955 meeting are: Chairman C. J. Chance, Tennessee; Vice Chairman, I. B. Byrd, Alabama; Secretary-Treasurer, Bernard T. Carter, Kentucky.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

W. R. Martin

Introduction

The Committee on International Relations has had an active year. Committee members have kept the Chairman informed concerning new developments in their respective areas, and the highlights have been passed on to the Society through the medium of Newsletters.

It is the responsibility of the Committee to keep the Society informed about the work of foreign technical agencies, international organizations, meetings, conferences, negotiations, exchange of persons and information, and related international matters. Such international activity is now so extensive that it is difficult to keep the Society properly informed concerning current developments. The Committee accordingly welcomes the Program Committee's departure from previous practice in reporting to the Society. Two experts in the international field, Mr. Herrington and Dr. Wright, will report on recent developments, and your Committee's report will summarize some of the important aspects of international relations.

During the year, international fisheries activity has played an increasingly important part in solving world-wide development, conservation, and technological problems. This international co-operation in world affairs falls into two broad categories. On the one hand, co-operative research and management agreements are effectively solving conflicting claims in international fisheries. Secondly, technical aid programs, principally by the Food and Agriculture Organization of the United Nations and by the United States, are contributing a rapid improvement in the production and distribution of fish. Mr. Herrington will report on the first category by outlining recent international negotiations and treaties. Dr. Wright will deal with the second category by reporting on a few examples of successful technical assistance programs.

Summary of Various Aspects of International Relations

The primary international activities in fisheries are conservation and development.

Fishery conservation is playing an important part in world affairs. The need for fishery conservation has been used by some countries to justify their attempts to extend their jurisdiction over broad areas of the high seas. Other nations are using international co-operation in conservation as the most promising approach to the solution of conflicting high-seas claims.

Equally important is the achievement of better utilization of world

fisheries resources by exploration for underdeveloped fish stocks, and by development of fish culture, improved methods of capture and new fish-handling techniques.

Conservation.—Co-operative management of international fisheries has continued to advance rapidly during the past year. Established Commissions have been very active, and negotiations for new agreements have been undertaken. A number of these developments warrant special mention.

The International Pacific Halibut Commission, under terms of the new convention, has adopted a split season and a maximum-sustained-yield approach to the preservation of the halibut fishery in the north Pacific. The 1954 catch exceeded all previous catches since the organization of the Commission, and exceeded the 1953 catch by approximately ten million pounds.

The International Pacific Salmon Commission registered good progress during the last year. As a result of its regulatory program, and removal of obstacles, the salmon runs in the Fraser River have recovered. The 1954 catch of about ten million fish was the largest in the history of the fishery in modern times.

The International North Pacific Fisheries Commission has organized a dramatic expansion in investigation of the marine life of the Pacific salmon. An extensive racial study is already revealing differences between salmon of the same species from different localities. The work will provide the basis for dividing the catch in accordance with the new abstention principle of the treaty.

The International Commission for the Northwest Atlantic Fisheries is making noteworthy progress with detailed statistics and research programs. The experimental mesh regulations introduced in the New England sub-area in 1953 is reducing destruction of small haddock precisely according to predictions, and efficiency of trawling has increased. In June of this year, the Commission recommended large-mesh nets for cod and haddock fishing in adjacent sub-areas.

The International Whaling Commission has adopted several important amendments to the schedule, including a reduced catch limit, a delay in the opening of the blue whale season, and re-opening of a large sanctuary area.

The Great Lakes Fisheries Convention has now been ratified by both Canada and the United States. Although informal co-operation, through the Great Lakes Fishery Committee, has been especially good in guiding research on the lake trout and sea lamprey, it is anticipated that the work will be greatly strengthened following the establishment of the Commission. Both countries are currently engaged in an ambitious attempt to control sea lampreys.

International Tuna Conventions are of current interest. The Inter-American Tropical Tuna Commission is functioning, and a treaty between Chile, Peru, and Ecuador has been implemented.

The United States-Canada Fur-Seal agreement may revert to a four-

power treaty. A meeting to discuss fur-seal problems will be convened in Washington in November, with representatives from Canada, Japan, Russia, and the United States.

The outstanding international fisheries event of the year was the International Technical Conference on the Conservation of the Living Resources of the Sea held in Rome in April. The conference, convened at the request of the General Assembly of the United Nations, has reported to the International Law Commission. It recognized the necessity of international co-operation in research, statistics, and regulation in high-seas fisheries.

To sum up, international conservation of fisheries is big business. Fisheries statistics have been greatly improved and we are now able to study the total yield of our important international fisheries. In most of the agreements we find an extensive research program, shared by those countries participating in the fisheries. International commitments have certainly stimulated North American research programs.

Our international relations in fisheries are in a healthy state. Agreements have been implemented and regulations have been effected well in advance of serious reduction in the abundance of our major fish stocks.

In considering our local, provincial or national fisheries problems, we have much to learn by following the contributions of international fisheries conservation. The effects of new agreements for abstention, quotas, mesh regulations, predator control, barrier removal, seasons, and sanctuaries will all be watched with considerable interest.

Development.—Great progress is being made in the development of world fisheries through technical aid programs. Our greatest contribution in this field is through the Food and Agriculture Organization of the United Nations. In addition, the United States has an extensive foreign aid program, and Canada is contributing in a smaller way.

The FAO Fisheries Division deals with four major fields of activity—Biology, Technology, Economics and Statistics, and Technical assistance. The headquarters is in Rome, and regional offices have been established for Asia and the Far East, Europe and the Near East, and Latin America. Some of the important FAO activities should be mentioned.

The FAO fisheries publications, Yearbook of Fisheries Statistics, World Fisheries Abstracts, FAO Fisheries Bulletin, and the Fisheries Study Series, are most useful. Fisheries Councils and training centers are being organized. An exhaustive World Survey of Living Aquatic Resources is being undertaken. FAO is providing leadership in development and management programs. A useful contribution is also being made in Bibliographic Services.

The largest field of FAO activity is the expanded Technical Assistance program. Experts have been recruited on short-term contracts as fisheries leaders for some thirty countries. Biologists are exploring for new fisheries, and assessing the potential for fish culture developments. Engineers are investigating improved fishing methods. Technologists are developing more advanced methods of handling and processing fish after capture.

Fellowships have been established for the training of fisheries workers.

Dr. Wright has described some examples of similar types of development work carried out by the United States. Some fifteen counties are being so assisted to varying degrees.

Canada's Fisheries Project in Ceylon under the Colombo Plan arrangements may be cited as an example of the widespread development programs.

Ceylon's population of over eight million is increasing rapidly. Fish is one of the few generally acceptable forms of animal protein. The low fish production and the relatively high fish prices result in a dietary deficiency.

Canda has tried to do three things: (1) help produce an immediate increase in fish supply; (2) conduct a fissheries survey to provide new equipment, and discover unused stocks to increase long-term production; (3) assist in the education of fishermen and those concerned with fisheries development.

Substantial unused stocks of groundfish have been discovered that can be successfully exploited by bottom trawling and longlining. Surface longlining for pelagic fish is another undeveloped way of increasing the catch. Three fishing vessels, a cold storage, a by-products plant, a machine shop, and funds for a fisheries harbour have been donated. A fisheries education program has been set up. The surveys, equipment and education will favour long-term increases of production, and avoid waste of catches.

The development programs carried on by Canada, United States and FAO are making an important contribution to world peace.

COMMITTEE ON NATIONAL-STATE RELATIONS

Willis King

The report by this Committee will consist of this brief statement, to be followed by three papers which deal with an important phase of National-State relations. This approach was arrived at during the year following correspondence between the Program Chairman, Fred Dickson of Georgia, and the Committee Chairman, Alex Calhoun of California. The Committee had, as early as November 1954, selected as the theme of its report, "How Can National-State Relations Be Improved." The subject was to have been developed by the five committee members, each following a similar procedure to (a) establish the present zone of responsibilities, (b) the extent of overlapping functions, and (c) present recommendations based on its findings and guided by the new North American Fish Policy. The Committee recognized the need to make such a study and report. Under the able chairmanship of Alex Calhoun, I had high hopes for making a substantial contribution to the field of National-State relations. I would like to point out that this plan was abandoned with some reluc-

tance. It is hoped that the subject can sometime be treated as originally planned for 1955. It is regretted that Dr. Calhoun cannot be present to fulfill his assignment as Committee Chairman.

The present program, as arranged by the Program Committee, deals with subjects of importance to State and Federal fishery workers. The first paper to be presented as a part of this panel is entitled, "Reorganization of the Fish and Wildlife Service." Mr. Ernest Swift, Assistant Director for Operations, has observed the work of the Service first as a Director of the Wisconsin Department of Conservation and recently from his present position. Shortly after the Survey Team, organized by Secretary Douglas McKay, made its report in June 1954, Mr. Swift was given the responsibility of placing its recommendations into effect. Just what has been done will be told by Mr. Swift.

The conservation and management of our Nation's water resources is a subject of great concern to both Federal and State workers. The utmost in cooperation is required to protect the public interest, further the development which our civilization demands, and yet provide the opportunities for continued recreational use. Two Federal agencies who deal with water resources in a broad, yet intensive way, are represented on this program. Their interests are centered primarily on different aspects of watershed development; the Corps usually operating on the larger streams and water areas, the Soil Conservation Service on the headwaters. The Engineers' Program will be presented by Major General Charles G. Holle, Division Engineer, South Atlantic Division.

("The Army Engineers' Program of Watershed Develolpment" was presented by General Holle.)

Many conservationists have long urged that the place to hold back water to prevent floods is on the headwaters. One method of accomplishing this is by the construction of small flood detention reservoirs. A new program is getting started in this field and we are pleased to have Mr. Edwin C. Ford of the Watershed Planning Branch, Soil Conservation Service, describe the program of his Service.

(Mr. Ford presented his paper, "The Development of Agriculture's Program of Water Conservation.")

EDITORIAL BOARD

Kiyoshi G. Fukano

Again the Editorial Board has failed to issue the Transactions for last year's meeting in advance of the current sessions. For that failure we extend our deepest regrets—but offer no apologies whatsoever. The explanation is simple. One does not send to the printer copy that has not been received. Your Editor did not receive the transcript from the Seattle meeting until May 25. In short, this considerable mass of unedited material arrived at a

time when page proof should have been in circulation. To add to our discomfort, this same tardy reporter kept the manuscript for a scientific article in his possession over the same unreasonably long period. We trust that the transcript of this present meeting can be produced more expeditiously.

To stay in character, may I urge again that those members who submit materials for the TRANSACTIONS do us the courtesy of reading and following the "Instructions to authors." These instructions are few, reasonable, and clearly stated. Yet they are ignored so consistently that the time required for editing surely is twice what it should be. The members of the Editorial Board must sacrifice evenings and week-ends needlessly and our members must tolerate delays of publication. The answer to earlier issuance of the TRANSACTIONS is largely in the hands of the authors.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

RICHARD B. MILLER

After an exchange of views among the seven Committee members, a theme for our report was chosen. This theme is "Methods of Increasing Production in Natural Waters." The theme was somewhat arbitrarily broken down into the following topics.

1. Reclamation of small lakes by poisoning. This technique has been used successfully in the west and some large-scale work is well underway in the mid-west. Mr. Pautzke will give us an account of the present status of this technique.

2. The use of hatchery products. The hatchery was the first tool for increasing fish production. Of recent years a great deal of work has been done which shows that this tool has been often seriously mis-used. Perhaps the pendulum has swung too far; perhaps we have erred in discrediting the hatchery to an extent where its real uses and values have become obscured. Mr. Wade will defend the modern hatchery in his treatment of this topic.

3. Lake and stream improvement. To a scientist the idea of increasing production of fish by lake and stream improvement is the most attractive. It is fundamental; it starts with first principles. Dr. Eschmeyer has prepared a review of this topic which he will present to you.

4. Population manipulation. Dr. Ferguson was originally slated to handle this topic. Upon going into it more thoughtfully we discovered that it was rather nebulous and hard to pin down, especially when we excluded reclamation by poisoning and general regulations. Dr. Ferguson and I discussed the general subject in Ottawa with several other fishery people. We agreed that production of desirable species has been increased in some localities by reduction of less desirable species—e.g., by partial poisonings, nettings. We also agreed that there was a large promise for increased

fish production in learning how to apply fishing pressure. Thus it has been shown that fishing whitefish and ciscoes very heavily, so as to reduce the age composition to the first two year classes has led to enormously increased production. On the other hand, in slow growing fishes like the halibut, reduced pressure has led to increased production. The topic was finally judged too broad and unwieldly for brief presentation.

5. Liberalized regulations. The wave of relaxation in size limits, seasonal limits and creel limits has led to a greatly increased harvest of warm water fishes. In a few states and in Alberta and British Columbia, similar liberalization of regulations is being tried on trout waters. No formal report on this topic is presented as good reviews have been already published.

6. Limnological research. The pure science of limnology is expected to provide the facts that may then be applied to the production of more fish. I have talked to a number of fishery biologists who feel that the routine collection of limnological data has proven a barren undertaking. Their feeling is that when one is working on a well-defined problem and making observations with a specific purpose in mind, then only do these observations prove to be of value. Unfortunately Mr. Wagner is unable to be here. In correspondence he has urged the adaptation of standardized limnological procedures.

7. Control of natural mortalities. This is a broad topic and could include predation, summer-kills, winter-kills and disease. Dr. Snieszko is confining his account to disease.

COMMITTEE ON COMMERCIAL FISHERIES

Lee S. Roach

Mr. Albert Tester is Chairman of the Committee on Commercial Fisheries and it was through his efforts that the present program was prepared with the concurrence of the Committee. On July 1 he left his position with the University of Hawaii to become Director of the Pacific Oceanic Fishery Investigations for the U. S. Fish and Wildlife Service and with travel and duties of his new position was unable to come to the meeting this year. He asked me to express his regrets.

As was the case with some of the other standing committees a change in plan regarding the presentation of the report on Commercial Fisheries was endorsed by the Executive Committee of the Society early this year. This is quite a departure from the previous custom.

Prior to this change the Committee had already made some probing efforts toward accumulating some facts under the previous system and it is only fair to credit such assistance at this time. For example, as one member of the Committee, my requests for information on part of the Great Lakes fisheries situation was answered very completely by R. N. Johnston, Ontario Department of Lands and Forests; W. Mason Lawrence,

New York Fish and Game Division; Tom Langlois, Ohio State Institute of Hydrobiology; Alfred Larsen, Pennsylvania Fish Commission; and Bob Cummins, Ohio Division of Wildlife. I imagine the other committee members had a similar response in their areas of responsibility.

I would like to introduce Mr. Harden F. Taylor who will present his paper entitled "Contribution of Commercial Fisheries to Welfare of the People."

(Prepared paper was presented by Mr. Harden F. Taylor)

"Commercial Fishing Potentials of the Pacific," will be given by Donald L. McKernan.

(Prepared paper was presented by Mr. Donald L. McKernan.)

WATER POLLUTION COMMITTEE

George E. Burdick

By amendment to the By-Laws of the Society, the duties of this committee are to maintain a continuous survey and keep the Society informed on major developments in the field of pollution research relating to fish and fisheries and of water pollution abatement, including pertinent legislation, and to make such recommendations to the Society as may be considered appropriate.

At present there is no roster of the agencies or individuals engaged in research on the effects of pollution or pollutants on fish life, or on the organisms comprising the necessary food chain for fish population. While the U. S. Public Health Service has prepared such a roster of pollution control agencies in the United States, it is based on public health and is composed primarily of the state health agencies and pollution control boards and commissions. These are not always the sole control or regulating agencies, even though charged with the review of treatment plans and issuance of permits for operation, since the right to exact penalties for pollution affecting fish life implies a certain measure of control or regulation by agencies that are given that privilege.

It was decided that major emphasis would be placed on the attempt to obtain as complete a coverage as possible of the control and research agencies operating in this field both in the United States and Canada. The 48 states were divided among the six members of the committee residing in the United States, and the Canadian Provinces were assigned to the Canadian member of the committee.

Covering all the states and provinces in one year would have presented an impossible task, so it was planned to circularize only about one-third of them this year. This would allow the opportunity for more effective coverage, at the same time placing the survey on a continuous basis covering a three-year cycle. It was believed that relations between the Society and the

agencies would be improved if too frequent requests for information could be avoided. Due to some misunderstanding some committee members contacted all the states on their lists. However, other information can be obtained without duplicating the agencies covered this year.

A report of this nature can do little more than highlight the most important aspects of the overall picture. While the coverage is not complete, as a time limit was set for the return of questionnaires to be included in this report, replies were received from 20 control agencies in 15 states and research questionnaires were returned from 5 provinces and 29 states. Sixty-two replies were received in all. The pertinent data has been summarized in a mimeographed supplement which is available at this meeting. A certain number of replies received too late for inclusion this year will be turned over to next year's chairman.

Many of the control agencies sent copies of the laws regulating their activities and regulations formulated by their agency. In particular the "Minimum Regulations for the Disposal of Industrial Wastes," adopted August 2, 1950, by the Washington Stream Control Commission is the most complete and comprehensive of any thus far received. This publication might well serve as a standard for those states whose laws permit the establishment of such regulations.

The control agencies of several states are presently emphasizing the formulation of comprehensive plans for pollution abatement on a watershed basis. After preparation they can serve as a blueprint for the enforcement phase of the abatement program.

Oklahoma reports the passage of two new laws, the effect of which cannot yet be evaluated. Amendment to the law in West Virvinia has removed the exemption of the coal industry from coverage and provides for the use of the right of eminent domain to obtain sites for treatment works. Louisiana reports that the sugar mill waste control order has reduced the impact of these wastes on fish life.

Among the new treatment methods in use to reduce pollution are spray irrigation for canning plant and poultry processing wastes, the latter reported in use in Kansas. Expansion of the use of sewage lagoons for sanitary wastes in the midwest and southwest has been occurring. Although not a treatment method, the Weyerhaeuser Timber Company's magnesium oxide process reported by the State of Washington should be of special interest to the pulp industry in the reduction of pollution loading.

In terms of general pollution reduction, there has been a great increase in the construction of sewage treatment plants in many sections of the country. Several western and midwestern oil companies are installing elaborate treatment plants and many new industries provide effective treatment before initiation of operations.

In the field of research on the effect of pollution, or pollutants, on fish and aquatic organisms, many studies have been made by control agencies, industrial concerns and by research organizations acting for certain industries. Pending settlement of litigation, these are not available. One of the most extensive of such studies concerns oyster mortality in the State of

Louisiana and involves studies on oil and oil field wastes, conducted by the Texas A and M Research Foundation and by certain oil companies, as well as work by A. E. Hopkins, later of the Gulf Coast Research Laboratory, for a sulphur company. The Louisiana Commission of Wildlife and Fisheries have also had studies conducted on this problem.

Due to the importance of the local fisheries, very extensive research activities appear to be centered in the Northwest in the states of Washington and Oregon. Oregon stands out as an example of the cooperative type of approach since associations have been formed between the U. S. Public Health Service, the Oregon State College Department of Fish and Game Management, the National Council for Stream Improvement of the pulp and paper industry, the Oregon Game Commission and the U. S. Fish and Wildlife Service. It is reported that this approach has greatly increased the effectiveness of the work.

In the entire cross-section of the country covered by this report, the situation is not so encouraging. The partial to complete returns from 29 states indicate that research is being conducted in only 15, though it is doubtful if in two of these more than fact-finding surveys are involved. It is somewhat better in the Canadian Provinces, where four out of six are engaged in some form of basic research, the other two conducting pollution surveys on a river basin basis.

Not many of the agencies concerned with control over pollution are doing research of this type. Out of 20 returns, only six indicate that any such studies are being made. Four of these are by fish and game departments where some measure of control over pollution affecting fish is retained; the other two represent joint studies by the control organization and these departments.

Among the 27 state agencies responsible for fisheries resources from which replies or information were received, only 11 are making any studies in this field and two of these consist in evaluation of the ecological relationships in polluted waters. Four of the 11 are engaged in joint or supported research with control agencies or with colleges and universities.

In consideration of these data, it is impossible to avoid the conclusion that state fisheries agencies, which might be expected to be most interested in evaluating the effect of pollution on the resources for which they are responsible, are doing too little in this phase of their field. In part, this may be due to the tendency over the past decade to center all pollution control activities in boards or commissions set up within or closely associated with state health departments, which are forced to operate on budgets which do not permit research on the fisheries problems involved, even if they so desired. Whatever the reason, it seems clear that little such research is being done by these agencies. It is believed that many states might well examine their fisheries program, in terms of their responsibility to obtain the knowledge necessary to safeguard aquatic life against the encroachment of pollution even if no administrative control is vested in their fisheries agency.

REPORTS OF SPECIAL COMMITTEES

COMMITTEE ON THE AMENDMENT OF THE CONSTITUTION AND BY-LAWS

Ralph Hile

Over a number of years sentiment has existed among many members of the Society for the establishment of a mail-balloting system whereby all members in good standing may participate in the selection of officers. In recognition of this sentiment the Chairman of the present Special Committee in 1953 circulated a petition for the amendment of the Constitution that would have established such a balloting procedure. After fair and open consideration, the amendment was defeated at our 1953 Annual Meeting in Milwaukee.

An identically worded proposal for the amendment of the Constitution came before our 1954 Annual Meeting in Seattle. This time, for a variety of reasons that need not be reviewed here, the proposal did not—could not—receive proper consideration and was defeated soundly.

To prevent further parliamentary difficulties such as those which developed in Seattle, the members at the same meeting adopted a resolution instructing the President to appoint a Special Committee whose duty it should be to handle the procedural details of bringing the mail-ballot issue before this Augusta meeting.

Immediately after our appointment by the President, we circulated a petition for an amendment of the Constitution that would establish a mail-balloting system. This petition received the necessary 50 signatures and the amendment was distributed to the members as part of the circular letter of July 30, 1955, from the President and the Secretary. Thus all constitutional requirements have been met for voting on the proposal at this meeting.

The proposed amendment to the Constitution merely establishes the principle of voting for officers by mail ballot. If it is adopted, we must amend the By-Laws to establish appropriate election procedure. As a start on this task we are placing before you tentative drafts of amendments to the By-Laws under the headings "Balloting for Officers" and "Nominating Committee." Both drafts may be amended as the members see fit.

We have further prepared a concise statement of major arguments for and against the proposed amendment to the Constitution. As a Committee we take no official attitude. We urge only that you give this matter most serious consideration and vote according to what you feel to be in the best interests of the Society.

Proposed Amendment of Article IV, Paragraph 4 of the Constitution of the American Fisheries Society

[The petition for the amendment was signed by 50 members in good standing and the proposal has been circulated. The amendment will accordingly be considered at this meeting. A two-thirds majority is required for adoption; no changes can be made in the wording.]

Election of officers shall be by ballot distributed to all active members in good standing, life members, and distinguished-service honorary members, and election shall be by a majority of those voting. In the event of the failure of any one of the candidates for an office to obtain a majority, the choice shall be made by majority vote of the members eligible to vote at the session at which the results of the balloting are announced. Decisions at meetings, including election of new members and of nonappointive standing committees, shall be by a majority of those present at any meeting; *except that* a two-thirds majority shall be required for a motion for amendment of By-Laws adopted pursuant to Article V; and *excepted further that* a three-quarters majority shall be required for the election of distinguished service honorary members.

Proposed Amendments to the By-Laws

[These proposed amendments to the By-Laws are intended to establish a workable election procedure in the event the proposed amendment to the Constitution, establishing a mail ballot, is adopted. The amendment on balloting for officers would add a new section to the By-Laws. The amendment on the Nominating Committee would replace Paragraph (a), Section 18, of the present By-Laws. The wording of these amendments is tentative; members in attendance may propose and adopt such changes as they may wish. A two-thirds vote is required for adoption of an amendment to the By-Laws.]

BALLOTING FOR OFFICERS

Not less than 45 days in advance of the next annual meeting the Secretary-Treasurer shall prepare and distribute to all active members in good standing, life members, and distinguished-service honorary members ballots carrying the slate of candidates for office submitted to him by the Nominating Committee; any qualified voter nevertheless may add to the ballot the name of and cast his vote for any member eligible to hold a particular office. These ballots shall carry the date of distribution and the warning that only those ballots returned and in the Secretary-Treasurer's hands within 30 days after that date will be counted. At the end of the 30-day period the Secretary-Treasurer shall assemble the ballots and place them in a sealed package which he shall deliver to the Chairman of the Nominating Committee not later than the first day of the next annual meeting.

NOMINATING COMMITTEE

The Nominating Committee is a standing committee responsible for the selection of a slate of candidates for offices and for membership on elective standing committee. The slate of candidates for offices, which shall consist

of [two candidates each for the positions of President, First Vice-President, and Second Vice-President and of one or two candidates each for the positions of Secretary-Treasurer and Librarian,] [two candidates for the position of Second Vice-President and of one or two each for the positions of President, First Vice-President, Secretary-Treasurer, and Librarian] shall be placed in the hands of the Secretary-Treasurer not less than 90 days before the opening of the next annual meeting. In the event of failure of the Nominating Committee to submit its slate of candidates for offices by the date stipulated in this paragraph, the President may dissolve the Committee and appoint a new one in its stead. At the annual meeting the Nominating Committee shall report the results of the balloting for officers and shall submit to the Society its slate of candidates for elective committees. The committee shall consist of five members in good standing, appointed by the President within 60 days after his election, who shall serve until they have submitted their report at the next annual meeting.

Shall We Adopt the Amendment to the Constitution Establishing a Mail Ballot for the Election of Officers?

ARGUMENTS FOR THE AMENDMENT

If we are to have a truly democratic Society, all members must have the opportunity to participate in the election of officers.

Only a small percentage of our members can attend our annual meetings. As things stand now the organization is dominated by a relatively small group that is present year after year. They select the officers and determine the policies of the organization. At times, small, tight cliques have developed, who have kept influential positions within their control over periods of years. Nominating committees too frequently have been "instructed" and not given full opportunity for free deliberation.

A mail-ballot vote will end this abuse of minority control and give all members a sense of belonging. Those who never are able to attend the annual meetings can feel they are truly members of the Society.

A mail-ballot vote further will prevent "stampeding" of annual meetings by local groups who by sheer weight of numbers can elect their own candidates regardless of the wishes of the Society as a whole. The organization of regions has been of great benefit to our Society, but development of strong sectionalism can do us injury.

Our Secretary has expressed his willingness to handle the preparation, distribution, and receipt of ballots and estimates the annual cost as only $125.

ARGUMENTS AGAINST THE AMENDMENT

Allegations of improper domination by a small group are hard to support. The success of most organizations depends on the initiative of a small nucleus of members who have genuine interest and are willing to do the necessary work. Judgments of nominating committees are not infallible,

but most selections have been made of men of proven willingness to work to further the Society's interest. All officers should be and most have been selected on the basis of past and potential service to the Society—not on mere eminence in the field. Mail balloting can lead to the election of "name candidates" unwilling to spend the time necessary for the proper performance of duties.

The argument of greater democracy does not hold since the Nominating Committee which selects the names to go on the ballots would have more arbitrary powers than heretofore. In recent years the members in attendance have several times refused to take that Committee's recommendations; the chance for countermanding the Committee by electing a write-in candidate would be remote. As for contacts with individual members, the establishment of regions has increased greatly the opportunities for attending meetings. Furthermore, circular letters keep them abreast of developments.

Regardless of the willingness of our present Secretary to handle details mail balloting will add greatly to his ever-increasing burden. If we add more to the presently onerous duties of this office, we may experience future difficulty in finding candidates willing to accept election.

COMMITTEE ON IMPORTATION OF SALMONID EGGS AND PORTS OF ENTRY

W. Mason Lawrence

This Committee was appointed by the President of the Society, pursuant to the resolution adopted at the 1954 Seattle meeting, to study the recommendation that ports of entry be established and to define the techniques by which all salmonid eggs entering or leaving this country, along with containers and equipment, be disinfected.

From information and recommendations gathered and considered, the Committee has reached the following conclusions:

1. It is highly important all salmonid eggs shipped between hatcheries together with the containers and equipment be properly disinfected whether such shipment is intrastate, interstate, or internation. Any hatchery is taking an unwarranted and unneeded risk if it permits eggs received from another source to be placed in its hatchery facilities before the eggs have been disinfected.

2. Upon advice of fish pathologists, the disinfectants recommended are based on a study described in the paper, "The disinfection of trout eggs contaminated with *Bacterium salmonicida*," by L. L. Gee and W. B. Sarles, Journal of Bacteriology, Volume 44, pp. 111–126, 1942. They found that the best disinfectants are sulfa-merthiolate and acriflavine (10-minute treatment with an 0.015 percent solution of sulfa-merthiolate

or 10-minute treatment with 0.185 percent solution of acriflavine). Acriflavine is not recommended for use with acid water which reduces its activity (Smith, W. W., Proc. Soc. Exp. Biol. Med., Vol. 51, pp. 324, 326, 1942).

In addition to disinfecting the eggs, all packing accompanying the eggs should be destroyed, all containers thoroughly disinfected, all utensils employed in contact with eggs sterilized, and all washings disposed of through channels having no connection with the water supply of the hatchery or of streams and lakes inhabited by salmonids.

3. Disinfection will not give complete protection against the transmission of all infectious diseases because some bacteria and viruses can be transmitted inside the eggs. Quarantine and inspection would be required in addition to disinfection to give effective control of the transmission of all infectious diseases.

4. The Committee after careful consideration has concluded that it cannot with the time and facilities available to it develop a workable plan for the establishment of ports of entry. It is respectfully recommended that the specialists in fish disease of the Federal, State and Provincial Governments are best equipped to develop and recommend a sanitary service to prevent the introduction and transmission of fish diseases and parasites; whether such sanitary service is based on a port of entry system or on an effective inspection system by the individual States or Provinces.

REPORT OF COMMITTEE ON IMPORTATION OF FISH AND FISH EGGS

H. S. Swingle

Among the important diseases which may be transmitted among live fish are furunculosis, ulcer disease, kidney disease, infectious dropsy, gill diseases, and all the virus diseases. On or in the eggs may be transmitted various virus diseases, ulcer diseases, furunculosis, dropsy and spores of various parasites. Even in cases where a disease is already present, transmission of pathogen from one area to another may be dangerous in introducing different or more virulent strains of the organism.

The aquarium fish trade is the largest importer into the United States of live fishes from foreign countries. The annual value of this trade is in excess of one million dollars. Professor George S. Meyers of Stanford University estimates that from 1,200 to 1,500 species of aquarium fishes have been imported into the United States from Germany, South America, Malayan Region, Ceylon, Africa and other tropical areas. He states (private communication) that "if there is fear that parasites or diseases will be imported, it is a little late to get worried. These wild fishes have been coming in increasing numbers since 1922. Water from tanks in which

they are kept goes into the sinks and on into the rivers all over the country and has been doing so for 30 years. And fish kept in outdoor pools during the summer have been getting loose during cloudbursts." Several imported species were reported established in Florida waters, but no evaluation of the effect of the imported aquarium fish trade upon diseases and parasites in natural waters has been made.

Importation of live trout from Europe into the United States has been reported on a trial basis, but no information is available indicating importation on a commercial basis. Trout eggs for hatching or for resale in various states are apparently imported from Europe to a limited extent, but no definite figures on the volume of this business could be obtained. Canada imports from the United States large numbers of trout eggs and exports in return eggs of the Atlantic salmon, *Salmo salar salar*.

There is apparently no importation from foreign countries of live minnows for bait. Millions of bait minnows cross state lines within the United States. These are seined from public waters or raised in private hatcheries and hauled by truck to areas far from their point of origin. One example is the fathead minnow seined from Wisconsin lakes which is transported and sold by the thousands as far south as Florida, some of which were found by Snieszko (private communication) to be infected with furunculosis. Another example is the goldfish produced in private hatcheries in Delaware, Indiana, Missouri and elsewhere, which is transported throughout the United States for sale as bait or as an aquarium fish. The volume of this interstate transportation exceeds 100 million minnows per year, valued at over two million dollars.

In order to find the present status of regulatory laws and inspections relating to the importation of live fish and fish eggs, a questionnaire was sent to all State Fish and Game Departments. No reply was received from Pennsylvania or Utah. The following resume therefore does not include these states.

The following 24 states had laws regulating the importation or planting in State waters of live fish and fish eggs from foreign countries and from other states: Arizona, California, Colorado, Florida, Iowa, Kentucky, Louisiana, Maine, Massachusetts, Minnesota, Missouri, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, Virginia, Washington, West Virginia and Wisconsin. Connecticut had laws introduced in the present legislature. Wyoming's laws concerning importations did not specifically apply to fish. The following 20 states had no laws dealing with the subject: Alabama, Arkansas, Delaware, Georgia, Idaho, Illinois, Indiana, Kansas, Maryland, Michigan, Mississippi, Montana, New Jersey, Oklahoma, Rhode Island, South Carolina, South Dakota, Texas, Tenessee and Vermont.

Of the 24 states having laws concerning importation, all had the power to prevent introduction of diseased and parasitized fish. However, two had no personnel qualified to make such inspections, two had personnel qualified to make such inspections, two had personnel qualified to inspect for parasites but not for diseases and the remaining 20 states believed they had

specialists qualified to make inspections for both or could obtain such help from state universities.

No state made inspections of imported aquarium fishes, and only 5 states (California, Florida, Maine, New Hampshire, and North Dakota) reported making regular inspections of other introduced fishes. Eleven states (Arizona, Colorado, Delaware, Kentucky, Louisiana, Missouri, Nebraska, Tennessee, Washington, Wisconsin and Wyoming) reported that occasional inspections were made. Nevada and Ohio were planning to begin this inspection service.

Only Maryland and Montana considered the danger of introducing disease and parasites with foreign importations of major importance at present. Other states were practically unanimous in agreeing that their greatest danger was from the importation of diseases and parasites on live fish and eggs from other states. In northern states the greatest danger appeared in the interstate traffic in trout and trout eggs. In other regions, especially the South, the greatest danger appeared from transportation of bait minnows.

No state reported the establishment of a detrimental species of fish due to foreign importation within recent years. Several reported the yellow perch, *Perca flavescens,* the Rio Grande tetra, *Anastynax mexicanus,* the bowfin, *Amia calva,* the bluegill, *Lepomis macrochirus,* and the brook trout *Salvelinus fontinalis* as undesirable introductions from other states.

The Rio Grande tetra was reported established in Arkansas, Louisiana and Oklahoma following its importation from Texas for use as bait. Mr. Marion Toole of Texas (private communication) writes that this fish is a tropical species which cannot stand cold winter temperatures (below 45° F.), but in areas where it has established itself sport fishing has remained good. Mr. Harry E. Shafer, Jr. of Louisiana (private communication) writes that established populations of these minnows were found in Lake Bistineau in northwest Louisiana and also in the Red River. Their importance is still to be determined.

In regard to the present disease and parasite problems resulting from importations, their evaluation is practically impossible because so few states have specialists working this field. Only 13 research projects on fish diseases and parasites were listed for the entire U. S. in 1954.[1] Inadequate information is available concerning the diseases and parasites present in State, Federal and private hatcheries, and even less concerning those present in public waters. Red mouth disease, pink mouth disease and parasitic roundworms were reported brought in with foreign importations. Many states reported establishment in their waters of columnaris, furunculosis, *Ichthyopthirius, Lernea* and other parasitic arthropods due to the importation of trout or bait minnows from other states.

Since the regulation of inland fisheries is a function of the states, it appears desirable that all should adopt laws regulating the importation of live fishes and fish eggs to safeguard these resources. As inspection of fishes

[1] Survey of Sport Fishery Projects, 1954. U. S. Fish and Wildlife Service Circular 26, 143 pp.

for diseases and parasites would be involved, qualified personnel in these fields should be available. Since specialists in these fields are scarce and the need for their services great, more research on diseases and parasites of fishes should be conducted by the states in order to train more men in this field and to develop needed control measures.

Because of the difficulty in inspecting for diseases in fish, it would be desirable for all states where fish are raised for sale in other states, or imported for resale, to establish an inspection service which would inspect those commercial hatcheries or holding facilities periodically, inspect each lot of fish prior to shipment, and furnish the shipper with a certificate of inspection. This certificate should then accompany the shipment to its destination. If the procedure were followed, occasional inspection of shipments upon arrival would be also needed as a further precaution. Because of the difficulties involved, some diseases and parasite would still evade detection, but these problems could gradually be solved.

It is believed that the laws or regulations adopted by the States contain the following provisions.

1. A permit should be required for the importation of live fish or fish eggs. This permit might be for a period of one year or for one shipment.

2. A certificate of inspection of the live fish and fish eggs from the originating state or country should be required listing the parasites and diseases present.

3. The importer should be required to hold the imported fish and fish eggs in special holding facilities for a period of several days so that they can be inspected for disease, parasites or obnoxious species before release for sale or into the water of the State.

4. The importer should be required to notify the State Inspection Service as to the expected date of arrival of each shipment and to treat, disinfect or dispose of diseased and parasitized fish and containers at his own expense as required by the Director following inspection.

5. Require the routine treatment of all imported fish with formaldehyde or other approved chemicals for control of protozoan parasites.

6. Require all fish to be transported into the State in water containing 1 p.p.m. acriflavin or other approved chemicals to prevent spread of disease while in transit.

ELECTION OF HONORARY MEMBERS

Upon submittal of petitions bearing the names of 10 members in good standing, the following were elected by unanimous vote to distinguished service honorary life membership in the Society:

Robert Ervin Coker, Chapel Hill, North Carolina

William Francis Thompson, Seattle, Washington

Albert Hazen Wright, Ithaca, New York

REPORTS OF SESSIONAL COMMITTEES

TIME AND PLACE COMMITTEE

FRED A. THOMPSON

The Time and Place Committee received eight requests from organizations for the Society to meet in their respective areas in 1957. These requests were considered in joint session with the corresponding committee of the International Association of Game, Fish, and Conservation Commissioners. Serious consideration was given to geographical location and since the Southwest had not received a convention, the committee recommended that the Society meet in Las Vegas, Nevada, in 1957.

AUDITING COMMITTEE

EDWARD SCHNEBERGER

The Auditing Committee has examined the books and records of the Secretary-Treasurer for the fiscal year beginning July 1, 1954, and ending June 30, 1955. A detailed check of the receipts against the expenditures shows that all accounts balance and all funds are accounted for.

There are two items that we believe should be called to the attention of the Society and that the incoming President and Executive Committee should act upon as soon as possible. These items are Fidelity bond for the Secretary-Treasurer and expenses of the Secretary-Treasurer to the mid-year meeting of the Executive Committee.

At present the Secretary-Treasurer is under a $7,500 bond. In view of the fact that he handles nearly $10,000 cash annually and, also, that the maturity value of bonds and securities approximate $14,000, we recommend that the Fidelity Bond for the Secretary-Treasurer be increased to $25,0000. This can be done at a relatively small additional cost to the Society.

Since the attendance of the Secretary-Treasurer at the mid-year meeting of the Executive Committee is of vital importance to the Society it is recommended that the expenses be recognized as an annual authorized expenditure. Since the Society is in excellent financial condition it is unreasonable to expect that either the Secretary-Treasurer or his employer bear these expenses.

The Auditing Committee feels that Mr. Speaker and Mrs. Wright have done an excellent job in taking care of the business of the Society for the year and are duly deserving of the deepest appreciation the Society can extend. Especial thanks are also due the Iowa Conservation Commission for the many courtesies extended.

RESOLUTIONS COMMITTEE

H. H. MacKay

1. National Fish Week

WHEREAS, Fish and shellfish constitute a source of outstanding nutritional value, highly palatable, and available at reasonable prices, and

WHEREAS, The per capita consumption of fishery products in the United States and Canada is far less than it properly should be, and

WHEREAS, This low consumption can be attributed in large measure to the lack of appropriate publicity and promotional campaigns on behalf of fish as food, and

WHEREAS, The National Fisheries Institute, the Shrimp Association of the Americas, the Maine Sardine Industry, the Fisheries Council of Canada, and numerous other organizations, firms, and individuals have joined to organize and support a National Fish Week, October 3–8, 1955,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society tender its congratulations to those groups and persons responsible for the initiation of a National Fish Week and urge upon its members full and whole-hearted support of this forward-looking enterprise.

2. Inland Fisheries

WHEREAS, The inland fisheries of the United States constitute a natural resource of great potential importance, and

WHEREAS, This potential has not been realized because of lack of information with respect to problems inherent in harvesting, processing, and marketing, particularly of species in great abundance but little utilized, and

WHEREAS, The United States Fish and Wildlife Service has very recently begun an analysis of these problems with respect to the Great Lakes and mid-western area with the view of determining a proper course of future action,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society commends the United States Fish and Wildlife Service for this forward-looking action, and urges that this study be expanded so as to cover the field of under-utilized fish populations throughout the United States.

3. Funds for Recreational Use of National Forests

WHEREAS, The recreational use of National Forests continues to grow in keeping with increased population of the Nation and increased leisure, and

WHEREAS, Many national forests are presently in urgent need of recreational facilities including but not limited to camp ground sanitation facilities, and fish and wildlife habitat development, and

WHEREAS, Funds for the development of the aforesaid recreational facilities are almost entirely lacking,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries So-

ciety does hereby petition Congress to hasten action on HR 1823 which would make available to the Forest Service funds for recreational improvement and upkeep, and fish and wildlife habitat development.

4. Integration of Wildlife Conservation Programs

WHEREAS, There is a definite need to integrate more closely wildlife conservation programs of State and Federal agencies dealing with water resources development to prevent loss of or damage to wildlife resources,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society go on record as urging Congress to give favorable consideration to the immediate passage of the bill S.2372 introduced by Senator McClellan of Arkansas which amends Public Law 732 to accomplish the objectives of the Society.

5. Amending the Federal Power Act

WHEREAS, Under the provisions of the Act of Congress of June 25, 1910 (36 Stat. 347), commonly known and referred to as the withdrawal from entry on public land laws, the Secretary of the Interior has, from time to time, by executive order, withdrawn from entry, sale or location under the public land laws and has reserved for power purposes, numerous power sites on the public lands of the United States many of which power sites are located on, along and adjacent to local nonnavigable streams of the several states, and

WHEREAS, The Federal Power Commission, under the provisions of the Federal Power Act, 41 Stat. 1075, 16 U.S.C. 818, also has made numerous withdrawals from the public lands of the United States and has reserved for power purposes power sites on navigable and nonnavigable waters of the several states, and

WHEREAS, Ever since the enactment of the Desert Land Act of 1877, if not before, it has been the established law that all nonnavigable waters then a part of the public domain became *publici juris,* subject to the plenary control of the states designated therein, with the right in each to determine for itself to what extent the rule of prior appropriation or the common-law rule of riparian rights should obtain, and

WHEREAS, It has always been considered by the American Fisheries Society that the Federal Government, as the owner of the public domain had the power to dispose of the land and the water composing it together or separately, and that under the Desert Land Act of 1877, if not before, Congress had severed the title to the land and the water and had established the rule that the land should be patented separately and that the government title to the land would not carry with it a water right but all nonnavigable waters were reserved for the use of the public under the laws of the several states, and

WHEREAS, The Supreme Court of the United States recently upheld the validity of a license issued by the Federal Power Commission to construct a hydroelectric project on lands of the United States, withdrawn for power purposes, on a nonnavigable stream, wholly within one state without the

consent of the state on the ground that the withdrawal site was a "reservation" and not "public lands," within the meaning of Section 3 (1) and (2) of the Federal Power Act, and

WHEREAS, The legislative history of the Federal Power Act clearly indicated that it was never the intention of the Congress to invest the Federal Power Commission with the authority, either expressed or implied, to usurp or encroach on the sovereign powers of the states to regulate the use of the waters of their nonnavigable streams; it being expressly provided in Sec. 9 (b) (16 U.S.C.A. 802b) of said Federal Power Act that said Federal Power Commission shall, before issuing a license, require proof of the applicant that he has complied with the State laws with respect to the use of the water and the bed and banks of streams, and

WHEREAS, The actions of the Federal Power Commission and the courts in this respect have and will continue to jeopardize and to curtail the states in their development of stream utilization and is likely to cause irreparable damage to the water, wildlife, fishery resources, agriculture and industry and to create havoc in the administration of the water laws in the states, all in contravention of long established public policy.

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society hereby does urge the Congress of the United States to enact legislation amending the Federal Power Act so as to compel the Federal Power Commission to require proof that applicants for a license have obtained prior approval of the state or several states as the case may be, in respect to the use of the waters and the beds and banks of streams, notwithstanding the fact that the project sought to be licensed is to be located on public lands or reservations of the United States which has been withdrawn for power purposes, and

BE IT FURTHER RESOLVED, That such legislation shall impose on the Federal Power Commission the duty to require such proof, as above-mentioned, whether or not the project shall have an adverse effect on the navigable flow or the navigable capacity of any navigable stream.

6. Importation of Fish and Fish Eggs and Ports of Entry

WHEREAS, The reports of the special committees of the Society on (1) Importation of Salmonoid Eggs and Ports of Entry, and (2) Importation of Fish and Fish Eggs presented at the annual meeting of the American Fisheries Society, emphasized the danger of introduction and transmission of infectious diseases and parasites of fish through importation and transportation of fish and fish eggs, and

WHEREAS, These reports contain recommendations and suggested procedures for the development of a sanitary service to prevent the introduction and transmission of infectious diseases and parasites of fish,

NOW, THEREFORE, BE IT RESOLVED, That the Secretary of the Society transmit copies of the reports of these committees to each Federal, Provincial and State Fisheries agency with the request that appropriate consideration be given to the recommendations contained in these reports.

7. Water Pollution

WHEREAS, There is continuing need to strengthen and extend the Water Pollution Control Act, and

WHEREAS, The Senate Bill S. 890 passed the Senate and was reported favorably to the House by the House Committee on Public Works (House Report No. 1446) with amendments which further strengthened the Senate Bill, and

WHEREAS, The great majority of the people of the United States are sincerely and genuinely interested in better and cleaner waters throughout the Nation, not only for domestic and industrial uses, but for recreation as well,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society hereby does urge the Congress of the United States to give prompt consideration to the Bill S.890 looking to its early enactment, and

BE IT FURTHER RESOLVED, That copies of this resolution be forwarded to the Clerk of the House, to the Chairman of the House Committee on Public Works, and to each member thereof, by the Secretary of this Society.

8. Pollution

WHEREAS, The American Fisheries Society views with deep concern the impact of pollution on our fish and wildlife resources, and on public health, and

WHEREAS, It is believed insufficient consideration is given to the research necessary to safeguard these resources and the public health from the effects of pollution,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society hereby does urge Federal, State and Provincial agencies concerned with the control and protection of fish and wildlife resources and public health to analyze their research programs looking toward that expansion required to promote effective control of pollution.

9. Thanks to Dr. William C. Beckman

WHEREAS, The usefulness of any serial publication is greatly enhanced by the availability of a general index covering a long period of years, and

WHEREAS, The users of the Transactions of the American Fisheries Society benefited greatly from the general index for Volumes 1–58 but were handicapped by the lack of a similar index for later volumes, and

WHEREAS, Dr. William C. Beckman has remedied this deficiency by his compilation of an index for Volume 59–82,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society in its Eighty-fifth Annual Meeting express to Dr. Beckman its deepest appreciation for his excellent and generous contribution, and

BE IT FURTHER RESOLVED, That a copy of this Resolution, endorsed by the President and by the Secretary-Treasurer be forwarded to Dr. Beckman as a memento of the Society's gratitude.

10. Appreciation of Hospitality

WHEREAS, The Augusta, Georgia meeting of the Society has been an outstanding success, and

WHEREAS, The members and guests of the Society have had available excellent facilities for enjoyment of the sessions and of recreational periods,

NOW, THEREFORE, BE IT RESOLVED, That the American Fisheries Society express its appreciation and gratitude to the Program Committee, through its Chairman, Fred J. Dickson; to Fulton Lovell, Director of the Georgia Game and Fish Commission, and through him to the State of Georgia, and especially to members of his office, and field staff for their efficiency in handling local arrangements; to Thomas D. Beckum, Clerk of Council, representing His Honor Mayor Hamilton, and through him to the City of Augusta; to the several organizations and individuals whose untiring efforts combined to make this meeting a success; to the press for its splendid coverage of the convention; and to the management of the Bon Air Hotel for the numerous courtesies extended to the convention delegates.

PROPOSALS FOR AMENDMENT OF THE CONSTITUTION

[The following proposal to amend Article IV, Paragraph 4, of the Constitution was signed by 50 members in good standing and circulated to all the membership in accordance with the Constitution. The proposal was defeated.]

Election of officers shall be by ballot distributed to all active members in good standing, life members and distinguished service honorary members, and election shall be by a majority of those voting. In the event of the failure of any one of the candidates for an office to obtain a majority, the choice shall be made by majority vote of the members eligible to vote at the session at which the results of the balloting are announced.

Decisions at meetings, including election of new members and of non-appointive standing committee, shall be by a majority of those present at any meeting; *except that* a two-thirds majority shall be required for a motion for amendment of By-laws adopted pursuant to Article V; and *excepted further that* a three-quarters majority shall be required for the election of distinguished service honorary members.

[The following Proposal to amend Article IV, Paragraph 4, of the Constitution was signed by 50 members in good standing and circulated to all members in accordance with the Constitution. The proposal was adopted.]

Decisions at meetings, including election of members, shall be by a majority of these present at any meeting; *except that* for a motion for amendment of By-laws adopted pursuant to Article V, a two-thirds majority shall be required; and *excepted further,* a unanimous vote shall be required for election of honorary members.

NOMINATING COMMITTEE

ALBERT S. HAZZARD

Our Committee has worked hard and has functioned effectively in providing this list of nominees, therefore, I take pleasure in presenting the report. I would like to preface the reading of it with an explanation of how we functioned.

We reviewed carefully the past officers and members of the various committees to distribute the work and to be sure that all parts of the country were properly represented. We did, however, make two exceptions. We felt that the Committee on Names of Fishes was functioning satisfactorily and since the present chairman, Reeve M. Bailey, was willing to continue and had requested that his committee be re-elected without change, we acceded to his request. The other exception was the Committee on Water Pollution. At first, we had thought to give the members of that committee relief, but after hearing George E. Burdick's fine summary of the work accomplished, we realized that they were only about one-third through a large job, therefore, we felt that the same members should be asked to continue to function with one change.

OFFICERS

President .....G. E. Sprecher, Wisconsin
First Vice-President .....Clarence F. Pautzke, Washington
Second Vice-President .....H. S. Swingle, Alabama
Secretary-Treasurer .....E. B. Speaker, Iowa
Librarian .....Howard A. Tanner, Colorado

COMMITTEE ON INTERNATIONAL RELATIONS

Richard Croker, California, *Chairman*
William W. Anderson, Georgia
William F. Carbine, District of Columbia
Milton C. James, Washington
John L. Kask, Ontario
Milton J. Lindner, Mexico, D.F.
Lee S. Roach, Ohio

COMMITTEE ON NATIONAL-STATE RELATIONS

Minor Clark, Kentucky, *Chairman*
Lawrence F. Miller, Alabama
Arthur M. Phillips, Jr., New York
Richard L. Stroud, District of Columbia
William H. Thompson, Oklahoma

Committee on Hydrobiology and Fish Culture

Gerald P. Cooper, Michigan, *Chairman*
Don F. Alderdice, British Columbia
Norman Benson, Tennessee
Jack Hemphill, Arizona
Burton P. Hunt, Florida
Peter A. Larkin, British Columbia
Robert F. Stephens, North Carolina

Committee on Commercial Fisheries

Leslie W. Scattergood, Maine, *Chairman*
Walter M. Alley, Montana
Edwin M. Barry, Maryland
Charles R. Foster, Washington
Donovan Moss, Alabama
Leonard Omstead, Ontario
Marion Toole, Texas

Committee on Names of Fishes

Reeve M. Bailey, Michigan, *Chairman*
Ernest A. Lachner, District of Columbia
Edward C. Raney, New York
William E. Ricker, British Columbia
William B. Scott, Ontario
Royal D. Suttkus, Louisiana
Loren P. Woods, Illinois

Committee on Water Pollution

George E. Burdick, New York, *Chairman*
Peter Doudoroff, Oregon
Gordon Gunter, Mississippi
R. H. Millest, Ontario
Eugene W. Surber, Michigan
Clarence M. Tarzwell, Ohio
Irvin E. Wallen, Oklahoma

PRESIDENT PRITCHARD: The procedure in handling these names varies. Is it the desire of the Society that we vote on these as they are read?

DR. GOTTSCHALK: I move the unanimous election of the Committees as prepared by the Nominating Committee.
[Motion was seconded and passed.]

PRESIDENT PRITCHARD: I declare the members of the Committee elected.
G. E. Sprecher has been nominated for the office as President. To preserve the democratic tenets of the institution, are there any further nominations from the floor?

DR. CORNELL: I move the nominations for the office of President be closed.
[The motion was seconded and passed.]

PRESIDENT PRITCHARD: I take great pleasure in declaring Mr. George E. Sprecher the duly elected President for the American Fisheries Society for the ensuing year. [Applause.]
Mr. Clarence F. Pautzke has been nominated for the office of First Vice-President. Are there any further nominations from the floor?

MR. VIOSCA: I move the nominations be closed.
[The motion was seconded and passed.]

PRESIDENT PRITCHARD: I am happy to announce that Mr. Clarence F. Pautzke has been elected First Vice-President of the Society for 1956. [Applause.]
The Nominating Committee has offered the name of Dr. H. S. Swingle for the office of Second Vice-President. Are there any nominations from the floor?

MR. KING: I move the nominations be closed.
[Motion was seconded and passed.]

PRESIDENT PRITCHARD: I am pleased to announce that Dr. Swingle has been elected Second Vice-President.
You have heard the nomination of Mr. E. B. Speaker for the office of Secretary-Treasurer and Dr. Howard A. Tanner for the office of Librarian. Are there any further nominations from the floor?

MR. THOMPSON: I move that the nominations be closed and that Mr. Everett Speaker and Howard Tanner be elected to office by acclamation.
[Motion was seconded and passed.]

CONCLUDING BUSINESS

PRESIDENT PRITCHARD: I would like to ask Dr. MacKay from Ontario and Dr. Donaldson from the State of Washington to accompany our President-elect, Mr. Sprecher, to the chair.

PRESIDENT-ELECT SPRECHER: Thank you very much. I consider this the highest honor that you can give anyone in fisheries' work and want to assure you that I will do everything I can for the Society during the coming year.

I am particularly happy to see the other officers and the members of the committees that you have elected. I am sure they are the highest type of men that you could have selected, not only from the Society but from the entire North American Continent.

PRESIDENT SPRECHER: Does anyone else have any business?

MR. GORDON: Mr. Chairman, I suggest that we give a rising vote of thanks to Dr. Pritchard for the fine way in which he has led this Society during the last year.

PRESIDENT SPRECHER: I don't know whether that requires a second. I think we ought to just start right in giving him some applause. [Rising loud applause.]

DR. CORNELL: Mr. President, under the order of other business, many of us are somewhat concerned about the problem of getting prospective employees and anxious employers together in the fisheries field.

At the present time, the American Fisheries Society is the trade organization of the fisheries profession. For that reason, Mr. President, I move that a committee be appointed to report at the next meeting for the purpose of determining in what way the Society might best serve its members in getting employees and employers together.

PRESIDENT SPRECHER: As I understand your motion, Dr. Cornell, you would like to have the Society consider the maintenance of an employment register.

Is there a second to that motion? [Motion was seconded and passed.]

MR. GORDON: Mr. President, I move we now adjourn the 85th meeting of the American Fisheries Society. [Motion passed.]

PRESIDENT SPRECHER: The 85th convention is adjourned.

Appendices

CONSTITUTION OF THE AMERICAN FISHERIES SOCIETY

(Revised 1955)

ARTICLE I

Name, Objectives and Purposes

1. The name of the organization shall be the American Fisheries Society, hereinafter referred to as the Society.

2. The objectives and purposes of the Society shall be:

(a) To promote the conservation, development and wise utilization of the fisheries, both recreational and commercial.

(b) To promote and advance the development and application of all branches of fishery science and practice, including aquatic biology, engineering, economics, fish culture, limnology, oceanography and technology.

(c) To gather and disseminate technical and other information on fishes, fishing, fisheries, and all phases of fishery science and practice.

(d) To hold meetings for the presentation, exchange, and discussion of information, findings and experience on all subjects and techniques related to fishes, fishing, fisheries, and all phases of fishery science and practice.

(e) By such other means as may be appropriate, to unite and encourage those interested in fishes, fishing, fisheries, and all other phases of fishery science and practice.

ARTICLE II

Membership and Election of Members

1. The membership of the Society shall be of the following classes:

(a) *Active Member:* Any person interested in the Society and in the furtherance of its purposes and objectives is eligible for election as an Active Member.

(b) *Life Member:* Any duly-elected active member, upon payment of the fee for life membership as specified in the By-laws, may retain his status as an active member throughout the remainder of his life and shall be exempt from any further payment of dues.

(c) *Sustaining Member:* Individuals, any sporting or fishing club, any society, corporation or other organization is eligible for election as a sustaining member.

(d) *Library Member:* Any technical, public, private, or other library may become a library member.

(e) *Official Member:* Any Federal, State, Provincial, or Territorial department or agency of the United States of America, Government of Canada, United Mexican States, or any other American Republic is eligible for election as an official member.

(f) *Patron:* Any person, society, club, firm, corporation, or other organization is eligible to become a patron.

(g) *Honorary Member:* Honorary members shall be of two classes, *ex officio* and *distinguished service.* The President of the United States of America, the Governor-General of the Government of Canada, the President of the United Mexican States, the Governors of the States and Territories of the United States

of America, the Lieutenant-Governors of the Provinces of Canada, the Secretary of the Interior of the United States of America, the Minister of Fisheries of Canada, and the Secretary of the Navy of Mexico shall be Honorary Members *ex officio*. Any other person of note, by reason of his professional or other attainments, outstanding service to the Society, or his official position, shall be eligible for election as a *distinguished service* honorary member.

2. Nominations for active membership, sustaining membership, library membership, official membership, and patron shall be submitted to the Secretary-Treasurer with the endorsement of at least one active member of the Society. Except as provided in paragraph 3, such nominations shall be presented to the members present at any regular or special meeting and shall be considered elected if they receive an affirmative vote of a majority of the members present at such meeting. Nominations for honorary membership shall be submitted with the endorsement of at least ten active members of the Society in good standing, and the unanimous vote of all members present at any regular or special meeting shall be required for election.

3. The Executive Committee, established pursuant to Article III, is authorized to consider and vote upon nominations for all classes of membership, except nominations for honorary membership, during the intervals between meetings. When so authorized by the Executive Committee, the President of the Society and the Secretary-Treasurer, acting jointly, may pass upon such nominations during the said intervals.

4. The names of elected members shall not be added to the membership rolls of the Society until they have paid such dues, fees or assessments for a period of at least one year as are enumerated in the By-laws adopted pursuant to Article V.

5. As used in this Constitution, and in the By-laws adopted pursuant to Article V, the term member "in good standing" means any active member, sustaining member, library member, or official member, whose dues are not more than one year in arrears, and any life member, honorary member, or patron; provided that only active members in good standing, life members, and distinguished service honorary members shall be entitled to vote.

ARTICLE III

Officers and Executive Committee

1. The officers of the Society shall be a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and a Librarian.

2. Only active members in good standing, life members, and distinguished service honorary members who have been in attendance at one of the two regular meetings preceding their nomination or election shall be eligible for such nomination or election to one of the offices named in Paragraph 1; *except that* the Librarian shall be exempt from the requirement of attendance at one of the two previous meetings. Members who accept nomination and are elected to hold one of the offices of the Society, are bound to perform their duties to the best of their ability and to advance the purposes and objectives of the Society.

3. Officers shall be elected and serve for a period of one year, or until the next regular or annual meeting, and shall (with the exception of the Secretary-Treasurer and the Librarian) be ineligible for reelection to the same office for a period of one year after the expiration of their terms of office.

4. The officers named in paragraph 1, the President of the preceding year, the chairman of any regional division established pursuant to the provisions of Article VI, and the chairman of any standing committees established in accordance with the By-laws adopted in accordance with Article V, shall constitute the Executive Committee. The Executive Committee is authorized to decide the policies of the Society, and to transact such business of the Society as may be necessary between regular or annual meetings.

5. In the event of the cancellation of a regular or annual meeting, the officers enumerated in paragraph 1 of this Article and the members of any standing or special committees established in accordance with the By-laws adopted in pursuance of Article V shall continue to serve until such time as a regular meeting can be scheduled at which new officers shall be elected and new committee members elected or appointed.

ARTICLE IV

Meetings and Voting

1. The Society shall meet once a year at a time and place to be decided upon by the membership at the preceding regular or annual meeting, or, in default of such decision by the membership, by the Executive Committee. Special meetings may be called by the President with the approval of the Executive Committee.

2. In the event of an emergency, the Executive Committee shall have the power to cancel a regular or annual meeting, or to change the place of an annual meeting; and in the event of such cancellation the Executive Committee shall have the power to schedule the next regular meeting.

3. A quorum at any meeting for the transaction of official business shall consist of at least twenty-five active members in good standing.

4. Decisions at meetings, including election of members, shall be by a majority of those present at any meeting; *except that* for a motion for amendment of By-laws adopted pursuant to Article V, a two-thirds majority shall be required; and *excepted further,* a unanimous vote shall be required for the election of honorary members.

ARTICLE V

Authorization for the Adoption of By-laws

1. The Society is authorized to adopt and to amend subsequently as may be required, in accordance with the provisions of paragraph 4 of

Article IV, such By-laws as may be necessary for the conduct of the business of the Society.

2. By-laws adopted pursuant to the provisions of this Article must include, but shall not be limited to, the following:

(a) Set forth the amount of annual dues and special fees or assessments for the various classes of membership of the Society, and deal with other matters pertaining to the finances of the Society.

(b) Prescribe the duties of officers of the Society.

(c) Provide for the establishment of and specify the terms of reference or duties and method of selection (by Presidential appointment or by election) of such standing committees, other than the Executive Committee, established in accordance with Paragraph 4 of Article III, and such sessional committees as may be necessary for the conduct of the business of the Society and the furtherance of its purposes and objectives. For the purposes of this subparagraph, (1) a standing committee is defined as one which is established permanently in the By-laws as a part of the basic organization of the Society; and (2) a sessional committee is defined as one constituted for the purpose of undertaking specific tasks at or in preparation for a regular or special meeting of the Society and is discharged upon submission of its report or completion of its business.

(d) Notwithstanding the provisions of subparagraph (c) of this paragraph, the President may appoint, or the Society, by adoption of an appropriate resolution, may direct the President to appoint special committees to undertake special assignments; and such authorization or appointments shall not require amendment of the By-laws, and such committees shall automatically be abolished on completion of their assignments or on the date of the next regular meeting, whichever occurs first.

(e) Provide authorization for such official publications of the Society as may be necessary in the furtherance of its purposes and objectives.

(f) Provide for the establishment and maintenance of any regional divisions of the Society established pursuant to the provisions of Article VI.

ARTICLE VI

Regional Divisions

1. A regional division of the Society may be established by the favorable action of the Society, pursuant to paragraph 4 of Article IV, upon a petition presented to it at any regular meeting by not less than twenty-five members of the Society in good standing resident in a particular geographic region.

2. Such regional division or divisions shall be organized in accordance with pertinent provisions of the By-laws adopted pursuant to Article V.

3. Each such regional division may adopt and amend from time to time its own By-laws, which shall conform to the provisions of this Constitution and By-laws of the Society adopted pursuant to Article V. The By-laws of regional divisions, after adoption and each amendment, shall be reviewed by the Executive Committee of the Society to insure conformance with the Constitution and By-laws of the Society. No By-laws of regional divisions or amendments thereof shall be considered effective until

such review by the Executive Committee of the Society has been completed and the chairman of the regional division has been notified in writing by the Secretary-Treasurer of the Society that such by-laws or amendments thereof are in conformity with the Constitution and By-laws of the Society.

4. Each regional division shall elect its officers, which shall consist of a chairman, vice-chairman and secretary. The chairman of any regional division shall be a member of the Executive Committee of the Society, and in his absence or inability to attend meetings of the Executive Committee the vice-chairman of that regional division may act in his stead. The secretary of any regional division of the Society shall serve as an assistant to the Secretary-Treasurer of the Society and shall carry out his duties in accordance with such procedures as may be determined from time to time by the Secretary-Treasurer of the Society.

5. All members of the Society who reside within a designated region in which a regional division of the Society may be established shall, upon election to membership and payment of dues prescribed in the By-laws, be considered a member both of such regional division and of the Society as a whole. Qualifications for membership in regional divisions shall conform to qualifications for membership in the Society. Regional divisions may elect active and life members only. The other classes of membership set forth in Article IV shall be elected only by the Society.

6. The regional divisions may, with the approval of the Executive Committee of the Society, levy such special fees, in addition to the dues of regular members of the Society, as may be necessary to meet any expenses of the regional divisions which are not properly chargeable to the regular funds of the Society. All regular Society dues shall be paid only to the Secretary-Treasurer of the Society. Any special fees collected by the regional division shall be disbursed by the secretary of the regional division in accordance with the By-laws of such regional division and the authorization of its officers and members.

7. The Executive Committee may allot to any regional division, from time to time, such sums from the treasury of the Society as may be necessary to further through the regional division the purposes and objectives of the Society. Such allotted funds shall be disbursed by the secretary of the regional division in accordance with its By-laws and the decisions of its officers and membership.

ARTICLE VII

Amendment of Constitution

1. This Constitution, after adoption in accordance with the provisions of the existing Constitution and By-laws, shall supersede such previously adopted Constitution.

2. The Constitution may be amended upon recommendation of three-fourths of the Executive Committee which shall be circulated in writing of the membership at least 30 days prior to any regular meeting at which a vote is to be taken, and upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

3. A petition for amendment of this Constitution signed by not less than 50 members in good standing, irrespective of any action relative thereto taken by the Executive Committee in pursuance of paragraph 2 of this Article, shall be circulated to the membership by the Secretary-Treasurer at least 30 days prior to a regular meeting, and such amendment shall become effective upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

BY-LAWS OF THE AMERICAN FISHERIES SOCIETY

Section 1.—Duties of the President

The President is responsible for the business and organization of the Society, shall make such appointments as are authorized in the By-laws, and shall exercise such other functions and responsibilities as may be determined from time to time by action of the Society or the Executive Committee. He shall preside at all meetings of the Society, and at all meetings of the Executive Committee, of which he is chairman.

Section 2.—Duties of the Vice-Presidents

The First Vice-President shall assume the duties of the President during his absence or in case of his inability to act. The Second Vice-President shall assume the duties of the President during the absence of the President or the First Vice-President or in case of their inability to act. Upon designation by the President, the First Vice-President or the Second Vice-President shall preside at sessions at regular or special meetings.

Section 3.—Duties of the Secretary-Treasurer

The Secretary-Treasurer, in his capacity as Secretary, shall be responsible for maintaining the official records of the Society, shall conduct its official correspondence, promote its membership, and shall make arrangements for regular and special meetings of the Society, and for meetings of the Executive Committee. He shall serve as parliamentary advisor to the President and chairman of committees to insure that the business of the Society is conducted in accordance with the provisions of the Constitution and By-laws.

The Secretary-Treasurer, in his capacity as Treasurer, shall receive and collect all dues, fees, accounts receivable, and other income of the Society, shall have the custody of its funds, and shall pay all accounts payable and other claims

which have been duly authorized and approved. He shall furnish a bond in the sum of $25,000, on surety, to be approved by the Executive Committee, the premium for such bond to be paid by the Society. The Secretary-Treasurer shall present an annual report to the Society.

Section 4.—Duties of the Librarian

The Librarian shall have the custody of the library of the Society, including its archives and printed publications, and shall have charge of the sale of extra copies of its publications. He shall transmit promptly to the Secretary-Treasurer monies received from such sales.

Section 5.—Expenses of Officers

No elected officer or committee member of the Society shall receive any salary or other compensation for his services. Clerical and other necessary expenses of elected officers and committee members may be defrayed by the Society provided that it has, through action at a regular meeting, or by vote of the Executive Committee in the event of an emergency during the interval between regular meetings, authorized such disbursements in advance.

Section 6.—Official Publications

The minutes and proceedings of all regular and special meetings of the Society and of any regional division established pursuant to Article VI of the Constitution, together with reports of officers and committees at such meetings, technical papers furnished by members and selected by the Editorial Board for publication, and the official membership list of the Society shall be published in an annual volume which shall be numbered in series with the preceding volumes and shall be entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY. Each member of the Society in good standing shall receive one copy of the publications issued; except that each official member shall receive three copies of the publications issued; and excepted further, that publications shall not be distributed to patrons and *ex officio* honorary members.

Section 7.—Presentation and Publications of Manuscripts

Only members in good standing may present papers, either by reading or by title, at annual meetings of the Society or submit them for publication by the Society; *except* that outstanding non-members invited by the President of the Society, or Secretary-Treasurer with the advice of the President, who present papers at any meeting shall be exempt from this requirement. No member may have listed on the program of any meeting of the Society or any regional division thereof, or present, or have published in any one volume of the TRANSACTIONS, more than two papers; and for purposes of this section joint authorship shall be considered in the same status as sole authorships.

Section 8.—Dues of Members

The dues of the various classes of members, payable to the Secretary-Treasurer of the Society, shall be as follows:

(a) Active member, $4.50 per annum.

(b) Life member, $75; payable, if desired, in two consecutive annual installments of $37.50 each.

(c) Library member, $4 per annum.

(d) Sustaining member, $10 per annum.

(e) Official member, $40 per annum.

(f) Patron, a single contribution of $250 or more.

(g) Honorary member, no dues.

All dues, fees, or other monies due the Society shall be paid in currency of the United States of America, or the equivalent in foreign currency at current rates of exchange in the United States of America.

Section 9.—Loss of Membership

Any member who fails to pay his dues for a period of more than one year shall be given written notice by the Secretary-Treasurer that his name will be removed from the membership list unless back dues are paid in full within 60 days from the date of such notice. Any member who has forfeited his membership may not be reelected as a member for a period of one year from date of forfeiture of his membership unless he has paid all back dues and has paid dues for one additional year in advance.

Section 10.—Committee on International Relations

The Committee on International Relations is a standing committee responsible for keeping the Society informed as to the work of foreign technical agencies, international organizations, meetings, conferences, negotiations, exchange of persons and information, and related international matters of interest to the Society, and shall recommend such action or participation by the Society as may be appropriate in the furtherance of the Society's purposes and objectives. It shall consider problems of legislation and implementation of international agreements relating to the interests, purposes and objectives of the Society. The Committee shall consist of seven members in good standing, who shall be named by the nominating committee and elected by the Society. The Committee shall report to the Society annually concerning its work.

Section 11.—Committee on National-State Relations

The Committee on National-State Relations is a standing committee which shall act as a coordinating and advisory board for the consideration of interstate and National-State fishery problems and programs in the United States of America. It shall also consider problems of administration of fishery

resources, and Federal and State legislation and the implementation thereof in the fields of fishery conservation and management. The Committee shall consist of five members in good standing, at least one and no more than two of which shall be an officer or officers of the United States Government, who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, which report shall include such recommendations for action by the Society as are considered appropriate.

Section 12.—Editorial Board

The Editorial Board is a standing committee responsible for the editing and publication of the proceedings of meetings, including technical papers and other manuscripts, and for their publication in the name of the Society. The Board shall consist of not fewer than five members in good standing of proven technical and editorial abilities, each of whom shall serve at the discretion of the President. Each President, immediately upon his election shall appoint the members of the Editorial Board, and shall designate the chairman for the coming year. The chairman of the Board shall be known as the Editor; each other member shall be termed Managing Editor, Associate Editor, Assistant to the Editor, . . . or given such other titles as may describe appropriately his functions and duties. The Editor shall assign duties to other members of the Board, and may solicit assistance, from time to time, for temporary periods from other members of the Society. The Board is authorized to establish and issue such standards and instructions to the membership as may facilitate its work. The Board shall report to the Society annually concerning its work.

Section 13.—Committee on Hydrobiology and Fish Culture

The Committee on Hydrobiology and Fish Culture is a standing committee which shall maintain a continuous survey and appraisal of research and applied work in the fields of aquatic biology, physiology, limnology, and oceanography as related to fishery science, fish culture, and fishery management. It shall develop and encourage the standardization and improvement of techniques, procedures, nomenclature, and measurements. The Committee shall be composed of seven members in good standing who are recognized specialists in various phases of fishery science and practice, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 14.—Committee on Commercial Fisheries

The Committee on Commercial Fisheries is a standing committee responsible for promoting and improving fishery techniques and the utilization of fishery resources for food and by-products, for the development and recommendation of standards of quality and sanitation, for the development and recommendation of standardized procedures for the collection and analysis of fishery statistics, and for related activities. The Committee shall be composed of seven members in good standing who are recognized specialists or authorities in fishery economics, technology, or the fishery industries, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 15.—Committee on Names of Fishes

The Committee on Names of Fishes is a standing committee responsible for the establishment and maintenance of a check list of common and scientific names of fishes, with the objective of achieving uniformity and avoiding confusion in nomenclature. The Librarian shall be custodian of the master check list. The Committee, in the furtherance of its duties, shall coordinate its activities with those of other societies and organizations throughout the world. The Committee shall be composed of seven members named by the nominating committee and elected by the membership, such members to be outstanding specialists in the fields of systematic ichthyology and fishery biology. The Committee shall report to the Society annually concerning its work.

Section 16.—Membership Committee

The Membership Committee is a standing committee responsible for maintaining and increasing the membership of the Society. The Committee shall take such measures as it deems appropriate and effective to stimulate interest in the Society and to further its purposes and objectives by interesting qualified persons in membership. The committee shall consist of the First Vice-President, who shall be chairman, of the Second Vice-President who shall be vice-chairman, and nine other members in good standing who shall be appointed by the President within 30 days after his election. The Secretary-Treasurer shall be an *ex-officio* member. The Committee shall report to the Society annually concerning its work.

Section 17.—Program Committee

The Program Committee is a standing committee responsible for arrangement of the program at the regular meetings, consisting of technical sessions for the reading and discussion of original papers, symposia on important topics, and exhibits of interest to the Society. It is the duty of the Committee to insure that the programs at the regular meetings are of high quality and achieve balance among the various fields

of interest and activity of the Society. The Committee may recommend to the President the issuance of invitations to outstanding non-members to present papers or addresses. The Committee shall consist of five members in good standing appointed by the President within 30 days after his election, who shall serve until the close of the next annual meeting.

Section 18.—Committee on Water Pollution

The Committee on Water Pollution is a standing Committee which shall keep the Society informed on major developments in the fields of research, abatement, and pertinent legislation concerning water pollution that relates to the fish and fisheries. The Committee shall maintain a continuous survey and appraisal of the research and applied work in the water pollution field, and shall report its findings annually to the Society. These reports shall include such recommendations for action by the Society as are considered appropriate. The Committee shall consist of seven members in good standing who shall be recognized specialists in the water pollution field, and familiar with pollution problems in the several regions of North America, who shall be named by the nominating committee and elected by the Society.

Section 19.—Sessional Committees

The President is authorized to appoint, from the members of the Society in good standing, prior to, or at the beginning of each regular meeting, such sessional committees as may be necessary for the conduct of the business of the Society and other authorized activities in conjunction therewith; including the following:

(a) Nominating Committee of five, which shall name a list of officers and members of Committees that are subject to election by the Society, which shall be presented to the members for action at a regular meeting. It is the duty of the Committee to insure that all persons named shall conform to the qualifications for the various offices and committee memberships set forth in the Constitution and By-laws. The right of any member to nominate a candidate for any office or committee membership from the floor during a regular meeting, or to second such nomination, is expressly reserved.

(b) Resolutions Committee of five, which shall draft and recommend to the Society for consideration and vote at a regular meeting such resolutions, including amendments of the By-laws, as may be considered prudent and necessary for the furtherance of the purposes and objectives of the Society and for the conduct of its business.

(c) Auditing Committee of three, which shall examine the accounts of the treasurer and report its findings to the Society, and shall consider the annual budget of the

Society prepared by the Secretary-Treasurer with the advice of the Executive Committee, and make recommendations concerning it for the action of the membership.

(d) Time and Place Committee of five, which shall consider and recommend to the membership for action, the time and place for subsequent regular meetings.

(e) Publicity Committee of three members, which shall draft, approve, and disseminate appropriate press notices and reports concerning the meetings of the Society and the proceedings thereat as may be appropriate and in furtherance of the purposes and objectives of the Society.

Section 20.—Order of Business

The order of business at regular meetings of the Society shall include, but shall not necessarily be limited to, the following:

1. Call to order by the President.
2. Address of the President on a timely subject of his choice.
3. Roll call of members (or determination that a quorum is present).
4. Action on nominations for membership.
5. Introduction of noteworthy guests and visitors.
6. Appointment of sessional committees by the President:
   a. Nominating Committee of five.
   b. Resolutions Committee of five.
   c. Auditing Committee of three.
   d. Time and Place Committee of five.
   e. Publicity Committee of three.
7. Report of the Secretary-Treasurer.
8. Report of the Librarian.
9. Report of the chairmen of regional divisions.
10. Reports of Standing Committees.
11. Reports of Special Committees.
12. Program of papers, symposia, and discussions.
13. Report of the Time and Place Committee.
14. Report of the Auditing Committee.
15. Report of the Resolutions Committee.

16. Report of the Nominating Committee.
17. Election of officers and members of such standing committees as are subject to election by the membership.
18. Installation of newly-elected officers.
19. Other business.
20. Adjournment.

Section 21.— Northeastern Division

(a) In accordance with the provisions of Article VI of the Constitution there is established a Northeastern Division of the American Fisheries Society which consists of members in good standing from the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and the District of Columbia in the United States of America, and the Provinces of New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, and Quebec of the Dominion of Canada.

(b) The Chairman of the Northeastern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Northeastern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 22.— Southern Division

(a) In accordance with the provisions of Article VI of the Constitution there is established a Southern Division of the American Fisheries Society which consists of members in good standing from the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and members residing in Cuba, Puerto Rico, the Virgin Islands, and other West Indian Islands.

(b) The Chairman of the Southern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Southern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 23.— Western Division

(a) In accordance with the provisions of Article VI of the Constitution, there is hereby established a Western Division of the American Fisheries Society, which consists of members in good standing from the states of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming and the Territories of Alaska and Hawaii of the United States

of America; and from the Provinces of Alberta, British Columbia, and Saskatchewan of the Dominion of Canada.

(b) The Chairman of the Western Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Western Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1954)

Please check each item below before the final typing of your manuscript and help reduce the costs of publication, save your Editorial Board much needless work, and avoid delay in the publication of the *Transactions.*

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals. Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced,** including titles, headings, legends for tables and illustrations, and literature citations. Write manuscript only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies or originals made with a worn-out ribbon will not be accepted.** Do not use thin paper; heavy bond is preferred.

3. **Margins** at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages must be numbered in consecutive order,** including tables and pages carrying legends to figures. Tables and legends of figures must be inserted near their place of reference in the text.

5. **Illustrations.** Make a separate page of each figure legend and limit the number of figures to those absolutely necessary to clarify or supplement text. Only sharp, glossy photographs can be used. Photostats will not be accepted. All drawings, charts, and diagrams should be prepared in waterproof India ink on high-quality paper or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. *All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend.* The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, and charts, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1. Do not use asterisks or other symbols to call attention to footnotes to tables.

7. **The title** of the manuscript, together with the author's name, division, or depart-

ment, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

TREATMENT OF DISEASES OF BROOK TROUT

John Edward Doe

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. **Inspect papers** in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in one of the two following forms. "A similar reaction to light was reported by Doe (1932)." "This type of reaction appears to be common (Doe, 1932)." Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus: (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below, to be placed at end of paper:

Literature Cited

Doe, John C., J. W. Brown, and H. W. Green

1939. Treatment of diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450–461.

List only bona fide publications under Literature Cited. Do not list personal communications, typewritten reports, or processed materials given only limited distribution but rather give the appropriate citations in text footnotes at point of reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and inaccurate. Help us correct this situation.

11. **Tables.** Every table except leader work must have a heading and must be typewritten on a separate page. In preparing tables please make certain that they are not too large to appear on a single printed page and that the arrangement conforms with the format of the *Transactions. Improperly prepared tables lead to the return of many manuscripts.* Number tables consecutively with Arabic numerals (1, 2, 3, etc.). Spell all words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length (millimeters)	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	65	April-September	$0.25

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to particular States, Governments, and organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, the State, the Province, the Republic, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Hoover Dam, Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 6.

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana.*

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5–Sept. 2 (but April–September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5–September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. **Numerals.** Spell out *isolated* numbers less than 10, but treat alike all numbers in a series of connected groups. For example: The nets contained nine bluegills. The catch included 9 bluegills, 20 smallmouth bass, and 123 pumpkinseeds.

Use figures for enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone but use numeral if part of a hyphenated expression: one-half inch; ½-inch mesh). Examples: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; fish 2 years 6 months old; 2-year-old fish; June 29, 1936; January 1938; the 20th day of March; 1937-1938; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enu-

meration exceeds 100: ten 12-room houses; twenty 6-inch bluegills; 120 6-inch bluegills.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five lake trout," but write "Two hundred fifty rock bass and 325 lake trout were shipped."

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentences: "This species is adapted to *cold water.*" "Ciscoes are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. **Papers which are too poorly written will be rejected.**

17. **Be definite in reference to species.** The full common name and the scientific name must be given for each species mentioned. Scientific names may be omitted from the title, if desirable, but must be given at first reference to the species in the text. Once given, scientific names need not be repeated. Follow the Society's official list of names. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "showed," "found," "gave," and "presented," are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *"This* was true in every *case." "The mortality* was *high* in every *pond."*

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. **Things to remember.** Well written papers are the product of careful thought and hard work. Usually they require repeated revisions that incorporate suggestions from discerning and honestly critical associates. Please make these revisions *before* submitting your manuscript.

Good writing is to a large extent a matter of good taste and good manners. Careless presentation and poor organization are rank discourtesy toward the readers.

Careless writing may save time but, once printed, a weak paper stands long as a discredit to its author.

20. **Abstract of paper.** Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board

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